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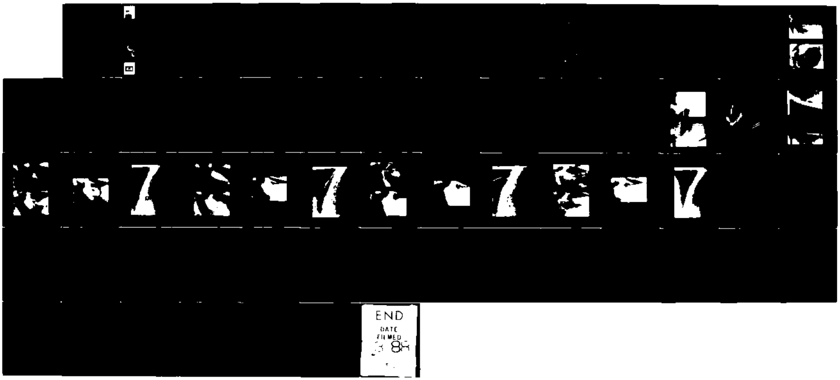

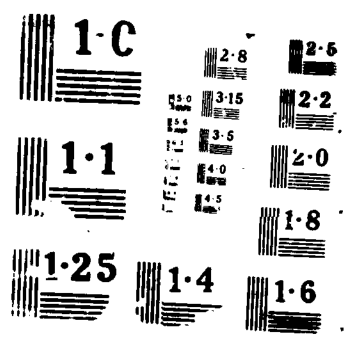
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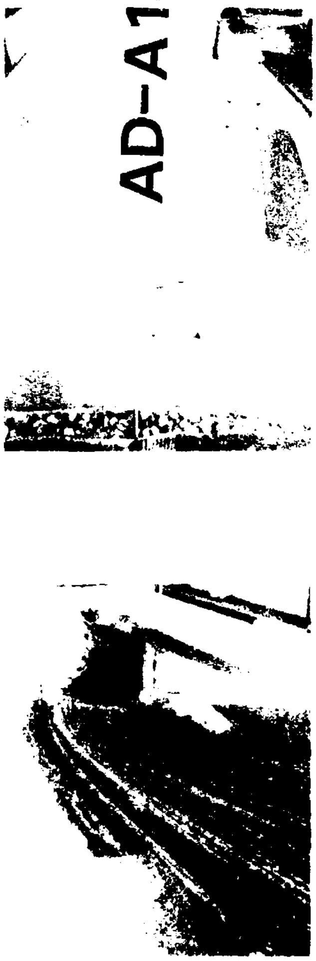

HYDRAULICS LABORATORY

TECHNICAL REPORT HL-87-11

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ISABELLA DAM SPILLWAY KERN RIVER, CALIFORNIA

Hydraulic Model Investigation

by

W. G. Davis

Hydraulics Laboratory

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
PO Box 631, Vicksburg, Mississippi 39180-0631

August 1987
Final Report

Prepared for US Army Engineer District, Sacramento
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Tests were conducted on a 1:50-scale model of Isabella Dam Spillway to determine the adequacy of proposed spillway, dam, and channel improvements. The model reproduced an area of the reservoir 800 ft wide by 1,100 ft long, the spillway, and the entire length of the exit channel.

Unsatisfactory flow conditions were observed in the vicinity of the spillway crest due to approach conditions to the spillway. Large cross waves, present in the exit channel just downstream of the spillway, resulted in occasional overtopping of the right wall. A grouted rock dike that provided satisfactory flow conditions at the spillway and downstream throughout the exit channel was placed adjacent to the existing spillway approach wall.

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PREFACE

The model investigation reported herein was authorized by the Office, Chief of Engineers (OCE), US Army, on 22 May 1984 at the request of the US Army Engineer District, Sacramento (SPK). The studies were conducted by personnel of the Hydraulics Laboratory, US Army Engineer Waterways Experiment Station (WES), during the period November 1984 to March 1986. All studies were conducted under the direction of Messrs. F. A. Herrmann, Jr., Chief of the Hydraulics Laboratory, and J. L. Grace, Jr., Chief of the Hydraulic Structures Division. The tests were conducted by Messrs. W. G. Davis and R. L. Stockstill, Locks and Conduits Branch, under the supervision of Messrs. G. A. Pickering and J. F. George, past and present Chiefs, respectively, of the Locks and Conduits Branch. This report was prepared by Mr. Davis.

Messrs. T. Munsey, OCE; T. Albrecht, South Pacific Division; and H. Huff, SPK, visited WES during the study to discuss test results and to correlate these results with current design work.

COL Allen F. Grum, USA, was the previous Director of WES. COL Dwayne G. Lee, CE, is the present Commander and Director. Dr. Robert W. Whalin is Technical Director.

CONTENTS

CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
acre-feet	1,233.489	cubic metres
cubic feet	0.02831685	cubic metres
feet	0.3048	metres
horsepower per foot	2,446.52	watts per metre
square feet	0.09290304	square metres

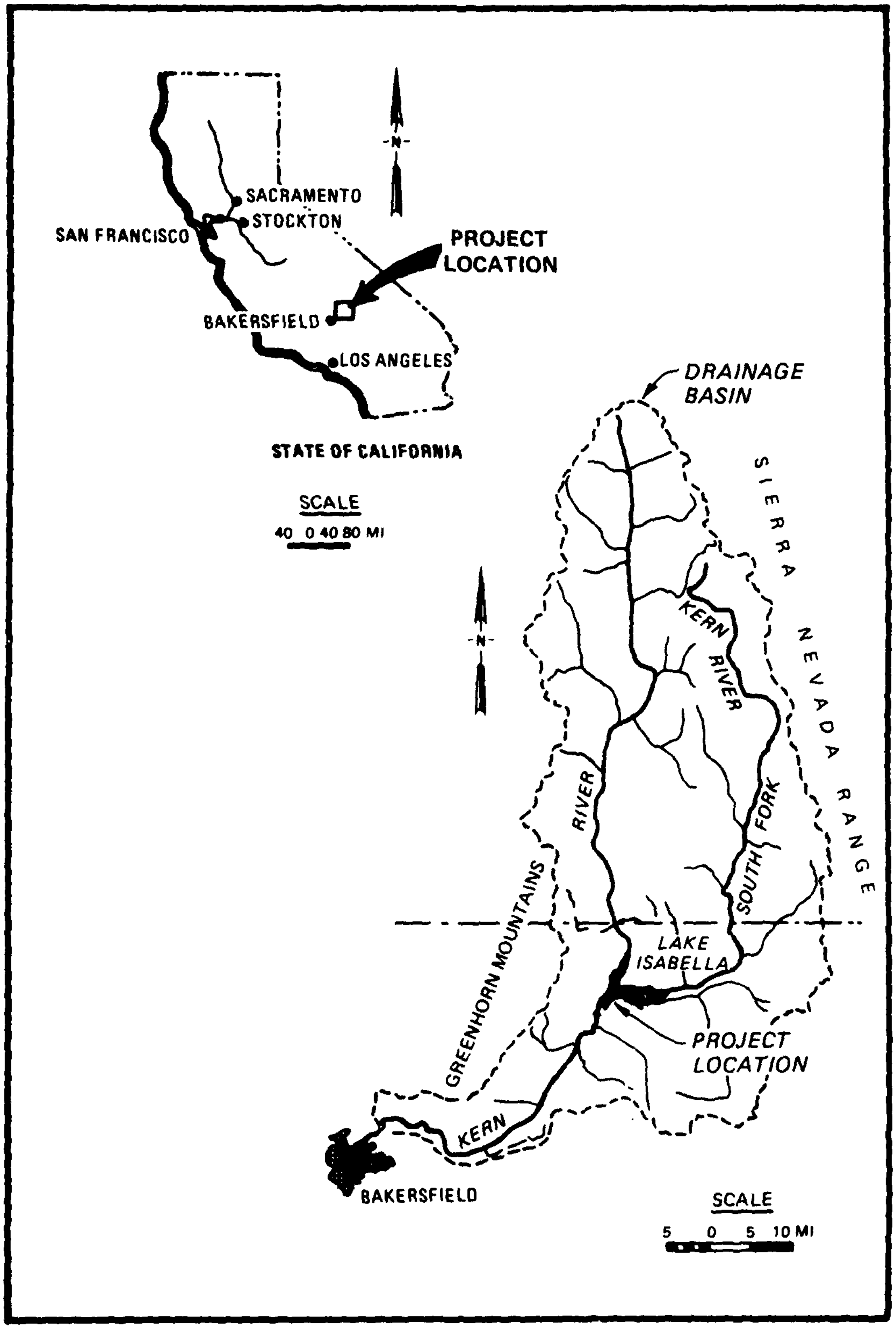

Figure 1. Location map

ISABELLA DAM SPILLWAY
KERN RIVER, CALIFORNIA

Hydraulic Model Investigation

PART I: INTRODUCTION

Prototype

1. The Isabella Spillway (Figure 1) is located about 50 miles* northeast of the city of Bakersfield, California, near the confluence of the north and south forks of the Kern River. The drainage basin comprises an area of 3,500 square miles with the headwaters located in the high Sierra Nevada mountain range. The original project comprises a 185-ft-high earthfill dam and an ungated concrete spillway in the left abutment of the main dam with a discharge capacity of 53,000 cfs, creating a reservoir with a gross storage capacity of 570,000 acre-ft, for flood control, irrigation, and related purposes.

2. Spillway adequacy studies, involving a revised Probable Maximum Flood (PMF), were made in 1978. These studies concluded that the Isabella Dam, as constructed, could not safely pass the new PMF which is 67 percent larger (by volume) than the original spillway design flood. Proposed modifications include raising the elevation of the top of the main dam 15 ft, and raising the height of the spillway approach wall, the sidewalls adjacent to the spillway, and the right side wall along the spillway exit channel to accommodate the design flood. An auxillary spillway will be constructed to pass that portion of the PMF that the existing spillway cannot handle; therefore, a design flood pool elevation (el 2,643.9**) was used for model tests.

Purpose of Model Study

3. A model study was conducted to evaluate the adequacy of the spillway

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* A table of factors for converting non-SI to SI (metric) units of measurement is presented on page 3.

** All elevations (el) cited herein are in feet referred to the National Geodetic Vertical Datum (NGVD).

and to develop desirable modifications to the spillway approach and exit channel. Specifically, the model study was to determine:

- _a_. Flow conditions and water-surface profiles throughout the spillway approach and exit channel.
- _b_. Discharge rating curves for various approach designs.
- _c_. Optimum approach flow conditions to the spillway.
- _d_. Exit channel modifications necessary to ensure that all flow is confined to the channel.

PART II: MODEL

Description

4. The 1:50-scale model reproduced an area of the reservoir 800 ft wide by 1,100 ft long, the spillway, and the entire exit channel (Figure 2, Plates 1 and 2). A portion of the 1.5- to 2.0-ft-diam stone (prototype) on the upstream side of the dam was reproduced near the spillway crest. The spillway crest was constructed of sheet metal with plastic-coated plywood side walls. The reservoir and overbank topography was molded in sand and cement mortar to sheet-metal templates, and the exit channel was molded of concrete with inlaid stone to reproduce the roughness of the rock cut prototype channel.

Model Appurtenances

5. Water used in the operation of the model was supplied by a circulating system. Discharges were measured with venturi and paddle-wheel meters installed in the flow lines and were baffled when entering the model. Velocities were measured with pitot tubes and propeller-type meters that were mounted to permit measurement of flow from any direction and at any depth. Water-surface elevations were measured with point gages. Different designs, along with various flow conditions, were recorded photographically.

Scale Relations

6. The accepted equations of hydraulic similitude, based on the Froudian criteria, were used to express mathematical relations between the dimensions and hydraulic quantities of the model and prototype. General relations for transference of model data to prototype equivalents are presented in the following tabulation:

a. Looking downstream

b. Looking upstream

Figure 2. The 1:50-scale model

Characteristic	Dimension*	Model:Prototype
Length	L_r	1:50
Area	$A_r = L_r^2$	1:2,500
Velocity	$V_r = L_r^{1/2}$	1:7.071
Discharge	$Q_r = L_r^{5/2}$	1:17,678
Volume	$V_r = L_r^3$	1:125,000
Weight	$W_r = L_r^3$	1:125,000
Time	$T_r = L_r^{1/2}$	1:7.071

* Dimensions are in terms of length.

Model measurements of discharge, water-surface elevations, and velocities can be transferred quantitatively to prototype equivalents by means of the scale relations. Experimental data also indicate that the model-to-prototype scale ratio is valid for scaling stone in the sizes used in this investigation.

PART III: TESTS AND RESULTS

Original Design

7. The model reproduced an area of the reservoir 800 ft wide by 1,100 ft long upstream from the spillway (Figure 2, Plates 1 and 2). Due to unsymmetrical approach conditions to the spillway, unsatisfactory flow conditions were observed along the right approach wall to the spillway for discharges above 50,000 cfs. With the design flood pool (el 2,643.9), a considerable amount of flow followed along the upstream face of the dam and plunged over the right approach wall. This produced very unsatisfactory flow conditions at the crest, which resulted in a significant reduction of the effective length of the spillway (Photo 1).

8. The top of the new exit channel wall was set higher than the theoretical computed water-surface elevation in an effort to contain the new PMF. However, with the design flood pool, significant cross waves developed in the exit channel (Photo 2), which resulted in occasional overtopping along the right wall at sta 13+85. Velocities measured with the design flood pool are provided in Plate 3. Water-surface profiles are shown in Plate 4 and listed in Table 1. A discharge rating curve is shown in Plate 5.

Alternate Designs

9. Tests of different modifications to the right approach wall were conducted in an effort to improve approach conditions to the spillway. The original right spillway approach wall was modified by raising the height of the wall vertically to el 2,649 along its entire length (Type 2 design), which resulted in a reduction in the spillway capacity as shown in Plate 5.

10. The Type 3 design approach wall (Plate 6, Photo 3a) was tested next and consisted of a quarter of an ellipse with a major axis of 100 ft and a minor axis of 90 ft placed tangent to the existing spillway wall at sta 9+84 and extending upstream to sta 8+15. With the design flood pool, the spillway capacity was increased from 115,500 cfs (original design) to 130,000 cfs (Plate 5). Flow conditions in the approach are shown in Photo 3. Velocities measured with the design flood pool are provided in Plate 6. Water-surface profiles are shown in Plate 7 and listed in Table 2. Occasional overtopping

along the right wall at sta 13+85 was observed in the exit channel (Photo 4).

11. The spillway approach was then modified by reinstalling the existing right spillway approach wall in the model and adding a grouted rock dike adjacent to and upstream of the existing approach wall (Type 4 design approach). A plan view and a dry bed photograph of the modified spillway approach are presented in Plate 8 and Photo 5a, respectively. Tests conducted with the Type 4 design approach installed indicated that this design performed satisfactory for all flow conditions observed. The approach conditions at the spillway were improved (Photos 5b and 5c), and the wave height was significantly reduced in the exit channel (Photo 6) as compared with the Type 1 and 2 designs. Velocities measured with the design flood pool are provided in Plate 8. Water-surface profiles are shown in Plate 9, and water-surface elevations are listed in Table 3. The spillway discharge was 125,000 cfs at the design pool (Plate 5). Thus, this design was considerably more efficient than the original design and slightly less efficient than the Type 3 design.

12. The spillway approach was then modified by reducing the length of the grouted rock dike adjacent to the existing approach wall by approximately 75 ft (Type 5 design approach). A plan view and a dry bed photograph of the modified spillway approach are presented in Plate 10 and Photo 7a, respectively. Excessive turbulence was observed in the vicinity of the spillway crest with desig flow conditions (Photos 7b and 7c). Water-surface profiles are presented in Plate 11, and water-surface elevations are listed in Table 4. Exit channel flow conditions are shown in Photo 8. The spillway discharge was 124,000 cfs with the design pool (Plate 12).

13. The length of the grouted rock dike was then increased approximately 40 ft (Type 6 design approach, Plate 13, Photo 9a), which is 35 ft shorter than the Type 4 dike. Tests conducted with the Type 6 design approach installed indicated that this design performed satisfactorily for all flow conditions observed. The approach flow conditions at the spillway (Photos 9b and 9c) were improved as compared with Type 1, 2, 4, and 5 designs. The Type 3 design approach (curved wall) improved approach flow conditions and yielded approximately a 3 percent higher discharge with the design flood pool as compared with the Type 6 design. However, the water-surface elevations in the exit channel were considerably higher than in the Type 6 design (Photo 10), and the curved wall would be very expensive and difficult to construct. Therefore, the Type 6 design approach is recommended for use in the

prototype. Water-surface profiles taken with the Type 6 design are shown in Plate 14, and water-surface elevations are listed in Table 5. A spillway rating curve is shown in Plate 12.

14. Certain hydraulic characteristics of the spillway exit channel were analyzed for the Type 6 design approach flow conditions with the design flood pool (Table 6). Plate 14 of Engineer Manual 1110-2-1603* shows the relation between the basic variables for a number of existing large spillways with energy dissipators to permit the designer to investigate operating experience for a unit horsepower of a magnitude comparable with the projected design.

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* Office, Chief of Engineers, US Army. 1965 (31 Mar). "Hydraulic Design of Spillways," EM 1110-2-1603, US Government Printing Office, Washington, DC.

PART IV: DISCUSSION OF RESULTS AND RECOMMENDATIONS

15. Tests to determine the adequacy of spillway, dam, and exit channel improvements for Isabella Spillway indicated that the original design with certain modifications would pass a desirable discharge at the design flood pool and that the exit channel would effectively contain design flood conditions.

16. Approach conditions to the spillway caused flow to plunge over the right approach wall reducing the effective length of the spillway. Also, large cross waves were present in the transition section just downstream of the spillway causing occasional overtopping of the right wall in the exit channel.

17. From the various types of design approaches tested, Types 3 and 6 were more effective in increasing the discharge capacity of the spillway. Although the Type 3 design approach wall performed satisfactorily, the Type 6 design approach, which utilizes the existing spillway approach wall with the addition of an adjacent grouted rock dike, was tested and found to provide satisfactory flow conditions for the full range of expected discharges. This design eliminated the destruction of the existing spillway approach wall and would be more economical to construct than the Type 3 design approach wall. Therefore, the Type 6 design approach is recommended for use in the prototype.

18. By using water-surface elevations measured in the model with the recommended improvements installed, the required wall heights of the prototype exit channel can be determined.

Table 1

Water-Surface Elevations, Discharge 115,500 cfs

Type 1 Design

Station	Elevation		
	Left Side	Center Line	Right Side
6+00	2,643.9	2,643.9	2,643.9
6+50	2,643.6	2,643.7	2,643.6
7+00	2,643.2	2,643.2	2,643.1
8+00	2,642.7	2,642.5	2,642.5
9+00	2,641.7	2,640.5	2,642.5
9+25	2,640.9	2,639.7	2,637.3
9+50	2,640.4	2,638.7	2,637.9
9+84	2,637.3	2,636.4	2,639.9
10+00	2,633.7	2,633.5	2,638.7
10+25	2,633.1	2,626.0	2,634.4
10+50	2,628.5	2,620.5	2,626.7
11+00	2,619.4	2,618.0	2,621.8
11+50	2,616.7	2,621.0	2,619.1
12+00	2,615.8	2,614.5	2,616.2
12+50	2,615.8	2,613.6	2,615.1
13+00	2,615.0	2,618.7	2,613.4
13+40	--	2,614.8	--
13+50	--	--	2,614.9
13+75	2,610.0	--	--
13+85	--	--	2,617.5
14+00	2,609.5	2,609.3	2,612.9
14+50	2,602.4	2,603.4	2,598.4
15+00	2,593.6	2,591.8	2,591.9
15+50	2,585.9	2,581.6	2,586.6
16+00	2,572.5	2,574.3	2,579.0
16+50	2,557.8	2,565.2	2,569.7
17+00	2,552.7	2,553.3	2,562.0
17+50	2,542.1	2,543.2	2,551.1
18+00	2,536.9	2,538.1	2,538.6
18+50	2,530.4	2,529.0	2,527.2

Note: Sides of channel are referenced to downstream direction.

Table 2

Water-Surface Elevations, Discharge 130,000 cfs

Type 3 Design

Station	Elevation Left Side	Elevation Center Line	Elevation Right Side
6+00	--	2,643.8	--
7+00	--	2,643.4	--
8+00	2,642.0	2,641.8	2,640.4
8+25	--	--	2,637.9
8+50	2,640.9	2,640.6	2,634.9
9+00	2,640.6	2,639.2	2,634.6
9+50	2,639.5	2,638.5	2,634.3
10+00	2,636.2	2,634.6	2,633.1
10+60	2,629.4	2,625.0	2,626.7
11+00	2,621.7	2,618.6	2,620.6
11+50	2,615.9	2,618.6	2,617.0
12+00	2,615.7	2,615.4	2,615.8
12+50	2,615.5	2,614.4	2,615.3
12+75	--	2,620.0	--
13+00	2,614.6	2,622.7	2,615.1
13+50	--	--	2,615.7
13+87	--	--	2,616.7
14+00	2,609.8	2,610.3	2,611.2
14+55	2,603.0	2,603.6	2,599.8
15+00	2,592.4	2,592.6	2,593.7
15+50	2,586.9	2,583.2	2,586.9
16+00	2,576.7	2,573.7	2,578.0
16+50	2,557.1	2,562.9	2,570.3
17+00	2,548.1	2,553.5	2,558.4
17+50	2,538.0	2,543.8	2,553.7
18+00	2,533.6	2,537.6	2,540.2
18+50	2,530.4	2,529.0	2,527.2

Note: Sides of channel are referenced to downstream direction.

Table 3

Water-Surface Elevations, Discharge 125,000 cfs

Type 4 Design

Station	Elevation Left Side	Elevation Center Line	Elevation Right Side
6+00	--	2,643.6	--
7+00	--	2,642.8	--
7+50	2,642.3	2,642.2	2,641.9
8+00	2,642.3	2,641.8	2,637.2
8+50	2,641.6	2,641.0	2,636.5
9+00	2,641.9	2,640.5	2,636.7
9+50	2,640.7	2,639.6	2,636.8
10+00	2,632.1	2,635.3	2,631.9
10+60	2,627.5	2,620.3	2,623.4
11+00	2,618.9	2,617.8	2,621.2
11+50	2,615.9	2,617.9	2,617.1
11+70	2,616.8	2,619.2	2,616.0
12+00	2,613.6	2,615.6	2,616.9
12+50	2,614.8	2,614.0	2,614.9
13+00	2,615.2	2,615.5	2,613.8
13+50	2,612.5	2,613.0	2,612.4
13+92	2,608.2	2,609.1	2,612.8
14+00	2,608.9	2,609.0	2,609.7
14+50	2,600.9	2,602.1	2,599.9
15+00	2,592.6	2,592.5	2,592.2
15+50	2,585.3	2,582.3	2,583.1
15+80	2,581.7	2,579.9	2,582.2
16+00	2,572.4	2,572.1	2,576.4
16+50	2,556.5	2,561.2	2,568.7
17+00	2,548.4	2,550.7	2,558.1
17+50	2,538.1	2,541.9	2,546.0
18+00	2,534.2	2,534.3	2,537.8
18+50	2,530.4	2,528.6	2,526.5

Note: Sides of channel are referenced to downstream direction.

Table 4

Water-Surface Elevations, Discharge 124,000 cfs

Type 5 Design

Station	Elevation		
	Left Side	Center Line	Right Side
6+00	--	2,643.8	--
7+00	--	2,643.2	--
8+00	2,642.6	2,642.4	2,642.1
9+00	2,641.5	2,640.5	2,637.8
9+50	2,640.6	2,639.0	2,634.6
9+75	--	--	2,628.9
10+00	2,632.2	2,634.4	2,636.0
10+50	2,628.5	2,620.5	2,624.2
11+00	2,618.0	2,617.5	2,622.3
11+50	2,616.1	2,617.4	2,616.4
12+00	2,615.1	2,615.9	2,616.5
12+50	2,614.8	2,614.0	2,614.9
13+00	2,615.1	2,615.9	2,616.5
13+92	2,609.0	2,608.0	2,614.1
14+00	2,592.5	2,592.4	2,592.1
14+50	2,600.8	2,602.0	2,599.7
15+00	2,592.5	2,592.4	2,592.1
15+50	2,585.2	2,582.2	2,583.0
16+00	2,572.3	2,572.0	2,576.5
16+50	2,556.4	2,561.0	2,568.8
17+00	2,548.3	2,550.8	2,558.0
17+50	2,538.0	2,541.8	2,546.0
18+00	2,534.1	2,534.2	2,537.9
18+50	2,530.6	2,529.2	2,527.1

Note: Sides of channel are referenced to downstream direction.

Table 5

Water-Surface Elevations, Discharge 126,000 cfs

Type 6 Design

Station	Elevation Left Side	Elevation Center Line	Elevation Right Side
6+00	--	2,643.9	--
7+00	--	2,643.1	--
8+00	2,642.4	2,642.0	2,641.5
9+00	2,641.6	2,640.4	2,637.8
9+50	2,640.5	2,639.1	2,634.7
9+75	2,639.4	2,631.4	2,633.6
10+00	2,635.3	2,634.9	2,631.8
10+25	2,632.4	2,627.9	2,628.9
10+60	2,627.8	2,620.1	2,627.2
11+00	2,619.2	2,618.5	2,620.9
11+50	2,617.4	2,618.5	2,616.3
11+75	--	2,620.6	--
12+00	2,616.4	2,616.0	2,617.3
12+50	2,615.6	2,612.5	2,615.7
13+00	2,616.1	2,618.9	2,614.3
13+50	--	--	2,615.5
14+00	2,609.5	2,609.4	2,609.8
14+50	2,602.6	2,603.1	2,599.2
15+00	2,592.0	2,592.2	2,593.5
15+50	2,586.4	2,583.0	2,586.4
16+00	2,576.2	2,573.2	2,577.5
16+50	2,556.7	2,562.3	2,570.0
17+00	2,547.6	2,553.0	2,558.0
17+50	2,537.5	2,543.3	2,553.2
18+00	2,533.0	2,537.0	2,539.6
18+50	2,530.0	2,528.6	2,526.7

Note: Sides of channel are referenced to downstream direction.

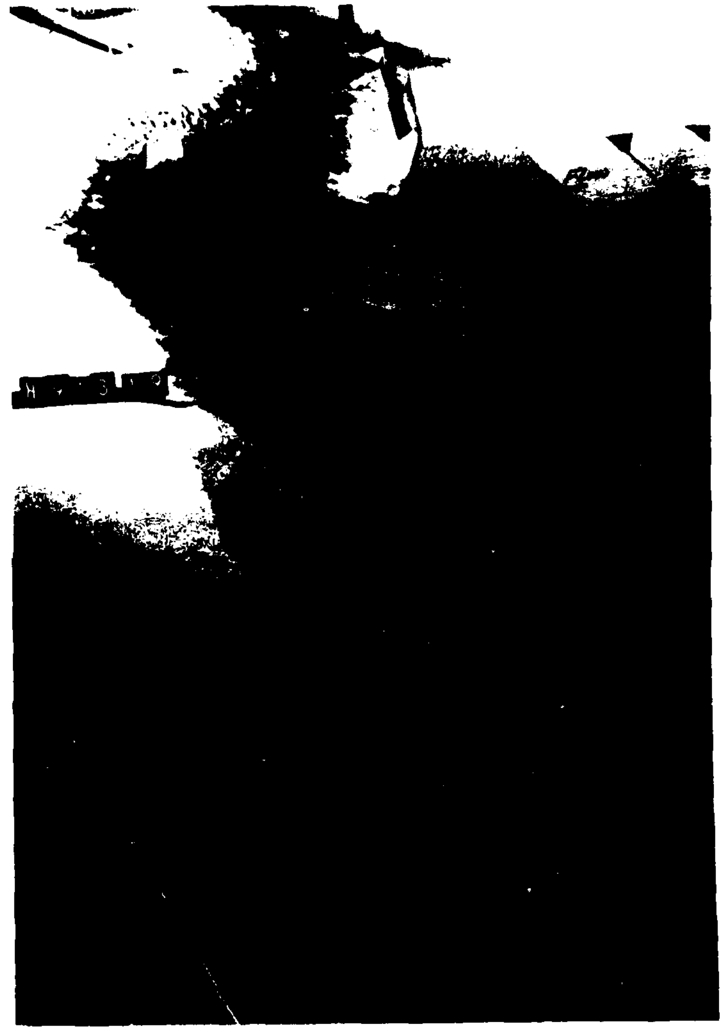
Table 6

Hydraulic Characteristics

Station	Depth ft	Area ft^2	Average Velocity ft/sec	Froude No. $V/\sqrt{gD}$*	Unit Discharge cfs/ft	Unit Horsepower hp/ft
10+60 (Spillway toe)	29.4	4,120	30.6	1.00	899	1,900
14+00	43.2	3,004	41.9	1.12	1,810	5,600
16+00	37.3	2,263	55.7	1.61	2,080	11,400
18+50 (Downstream end of exit channel)	28.1	1,799	70.0	2.33	1,969	17,000

* V = velocity; g = gravitational constant; D = depth of flow.

a. Dry bed



b. Discharge 115,500 cfs, design flood pool el 2,643.9

Photo 1. Spillway approach with Type 1 design approach (Continued)

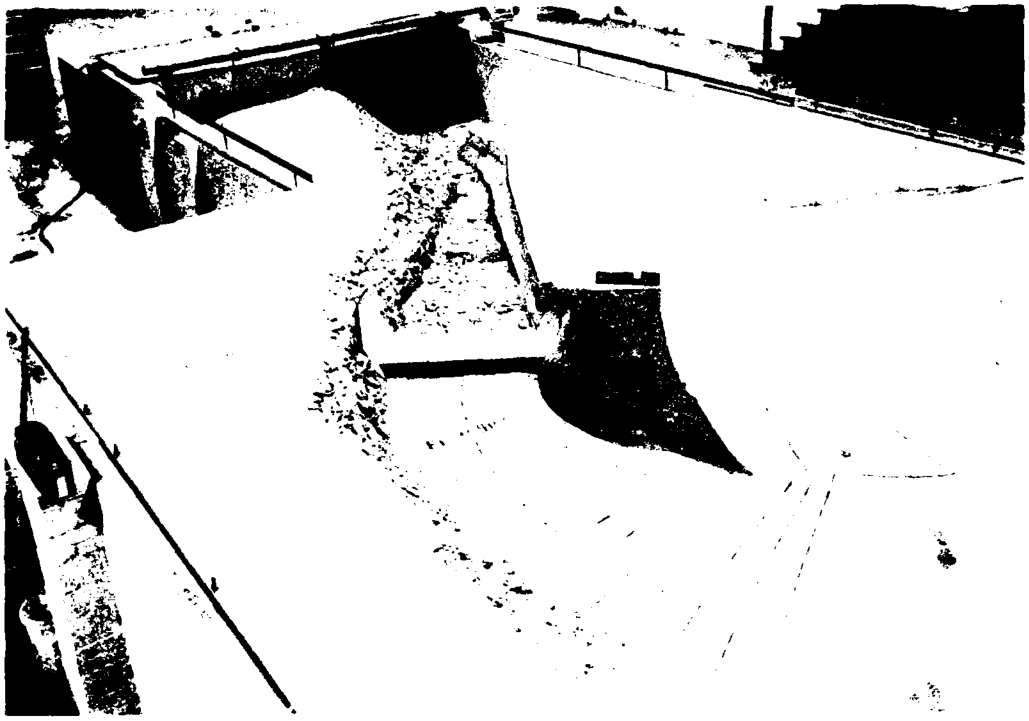
c. Discharge 115,500 cfs, confetti accents surface flow patterns; exposure time 14 sec (prototype), design flood pool el 2,643.9

Photo 1. (Concluded)

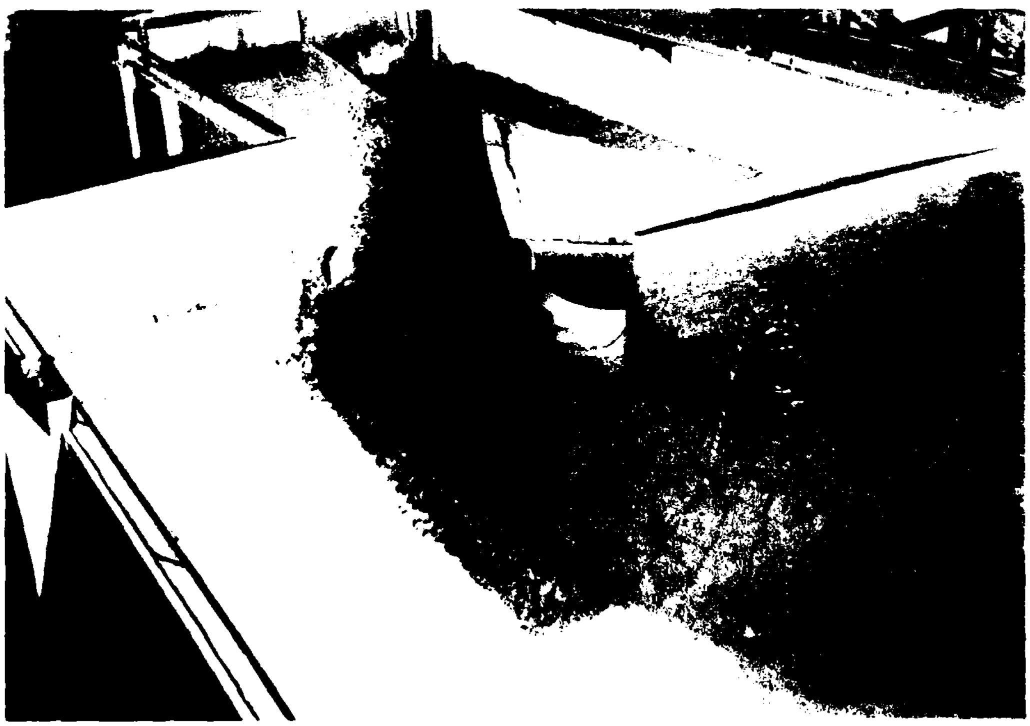
a. Dry bed

b. Discharge 115,500 cfs, design flood pool el 2,643.9

Photo 2. Exit channel with Type 1 design approach



a. Dry bed



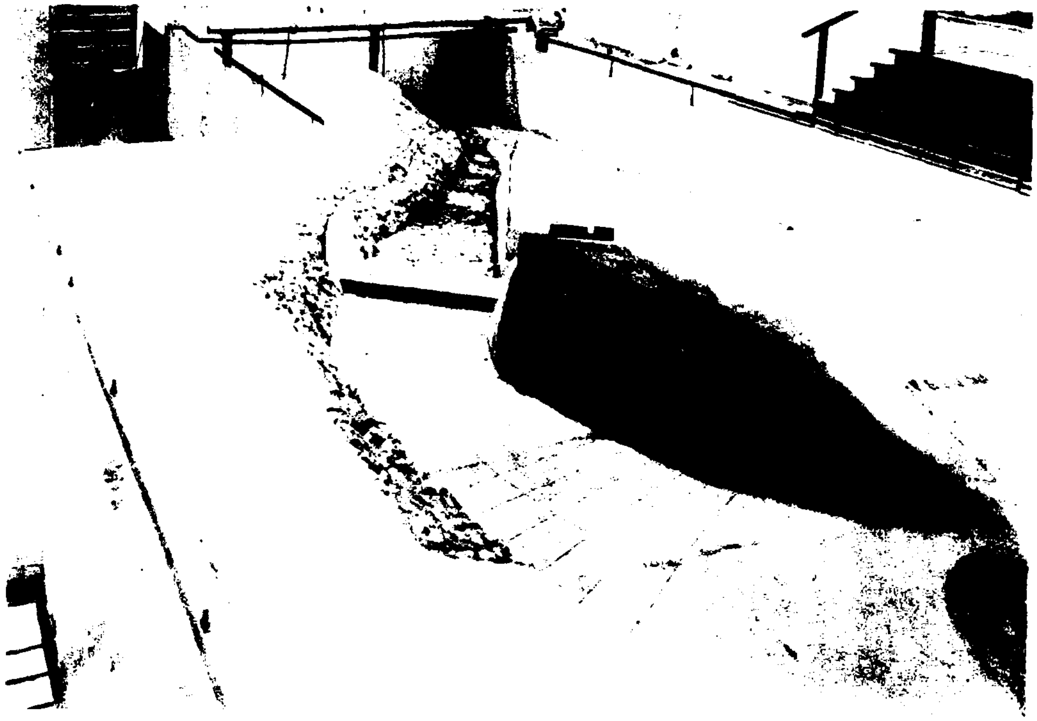
b. Discharge 130,000 cfs, design flood pool el 2,643.9

Photo 3. Spillway approach with Type 3 design approach (Continued)

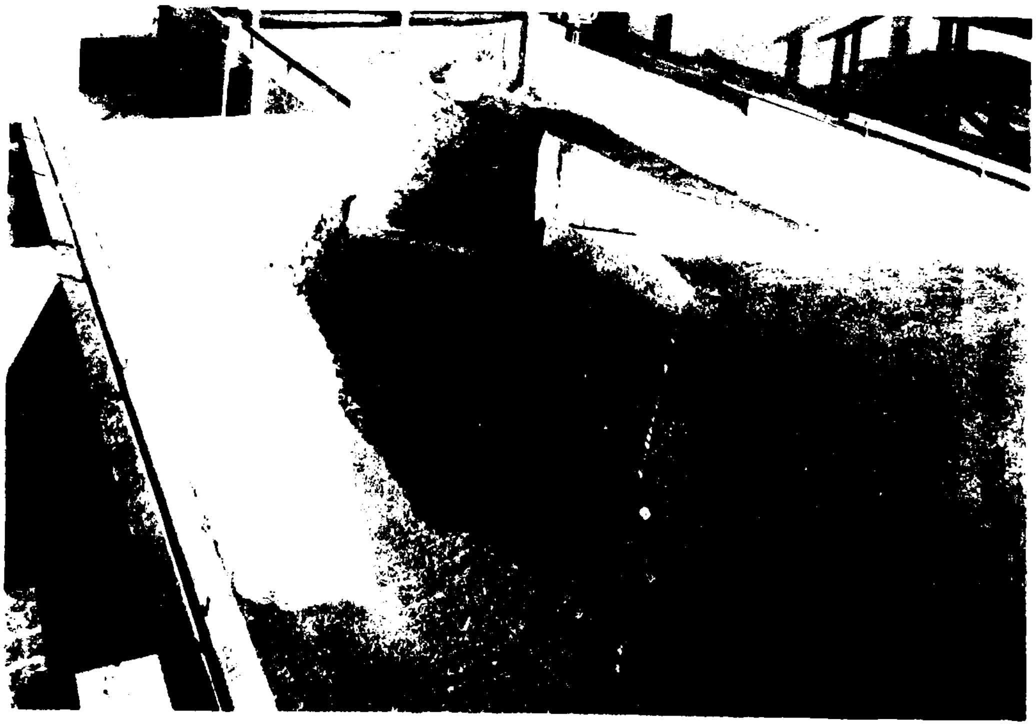
c. Discharge 130,000 cfs, confetti accents surface flow patterns; exposure time 14 sec (prototype), design flood pool el 2,643.9

Photo 3. (Concluded)

Photo 4. Exit channel with Type 3 design approach; discharge 130,000 cfs, design flood pool el 2,643.9



a. Dry bed



b. Discharge 125,000 cfs, design flood pool el 2,643.9

Photo 5. Spillway approach with Type 4 design approach (Continued)

c. Discharge 125,000 cfs, confetti accents surface flow patterns; exposure time 14 sec (prototype), design flood pool el 2,643.9

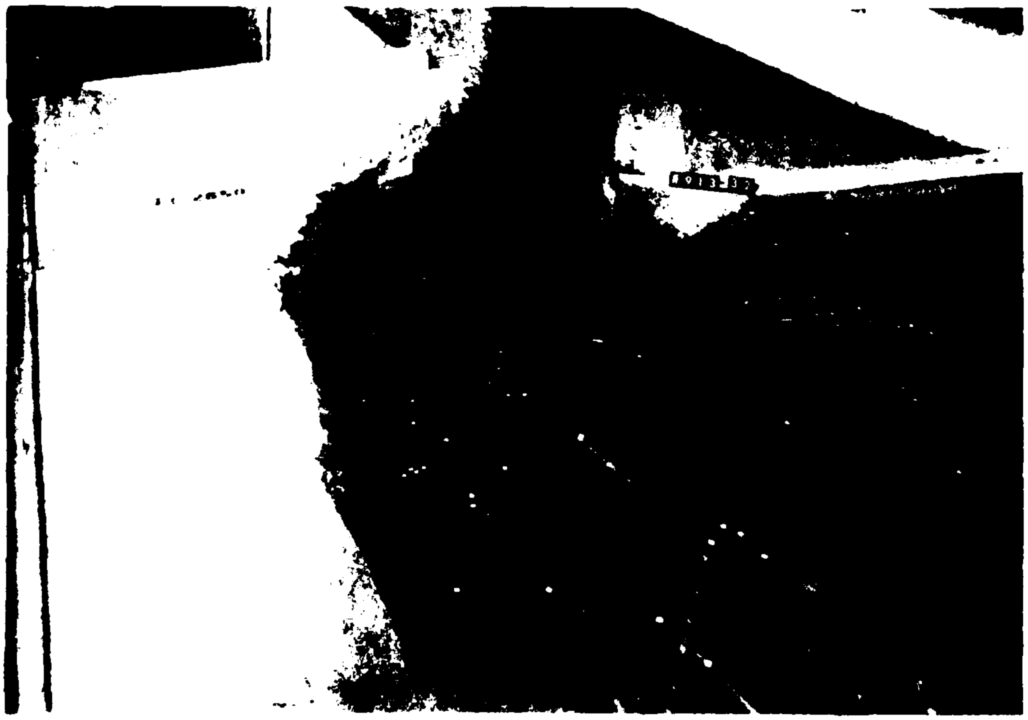
Photo 5. (Concluded)

Photo 6. Exit channel with Type 4 design approach; discharge 125,000 cfs, design flood pool el 2,643.9

a. Dry bed

b. Discharge 124,000 cfs, design flood pool el 2,643.9

Photo 7. Spillway approach with Type 5 design approach (Continued)



c. Discharge 124,000 cfs, confetti accents surface flow patterns; exposure time 14 sec (prototype), design flood pool el 2,643.9

Photo 7. (Concluded)

Photo 8. Exit channel with Type 5 design approach; discharge 124,000 cfs, design flood pool el 2,643.9

a. Dry bed

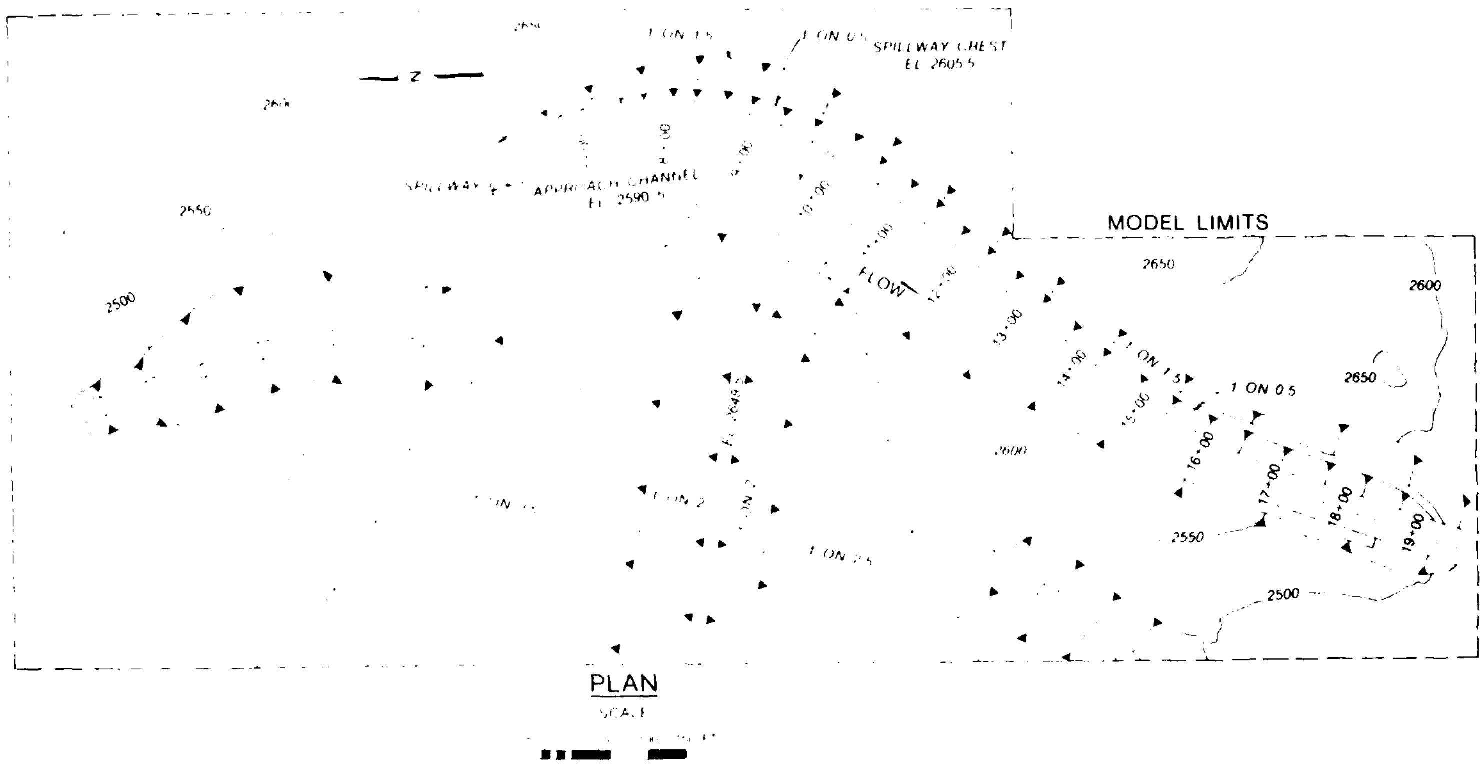
b. Discharge 126,000 cfs, design flood pool el 2,643.9

Photo 9. Spillway approach with Type 6 design approach (Continued)

c. Discharge 126,000 cfs, confetti accents surface flow patterns; exposure time 14 sec (prototype), design flood pool el 2,643.9

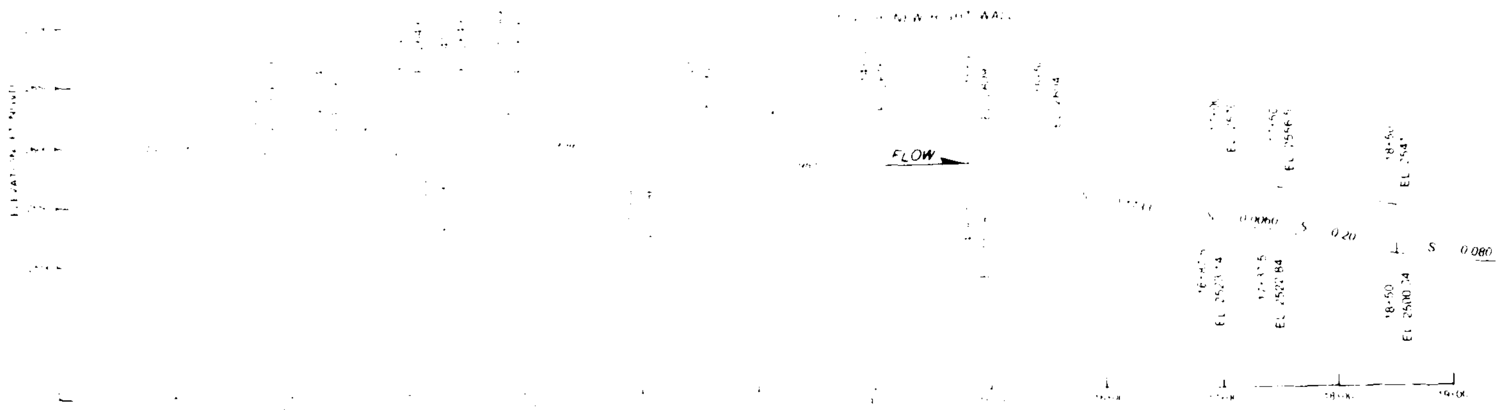
Photo 9. (Concluded)

Photo 10. Exit channel with Type 6 design approach; discharge 126,000 cfs, design flood pool el 2,643.9



PLAN VIEW

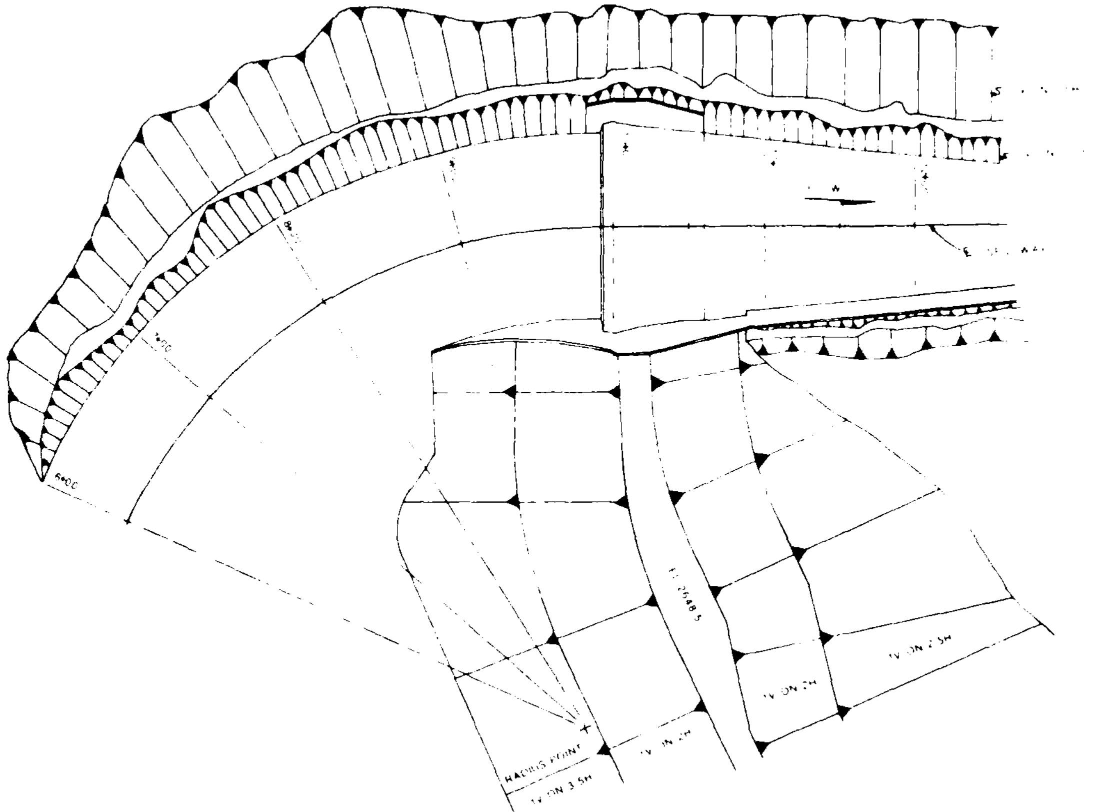
TYPE 1 SPILLWAY APPROACH
(ORIGINAL DESIGN)



ELEVATION

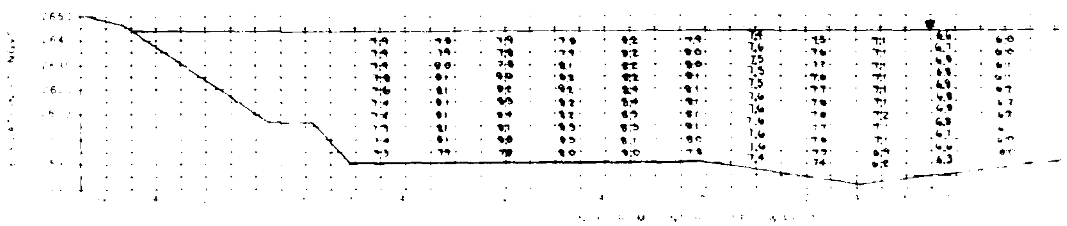
CENTER-LINE PROFILE
ORIGINAL DESIGN SPILLWAY APPROACH

PLATE 2

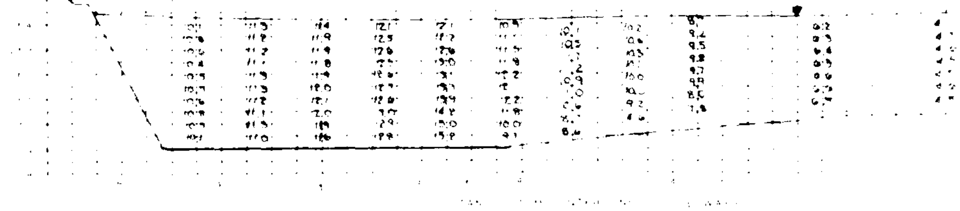


PLAN OF SPILLWAY

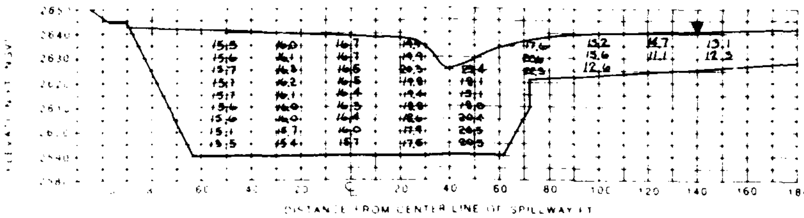
SCALE IN FEET



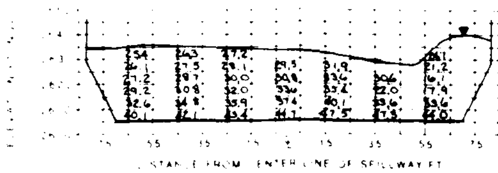
STATION 7+50



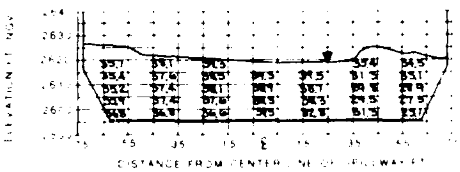
STATION 8+50



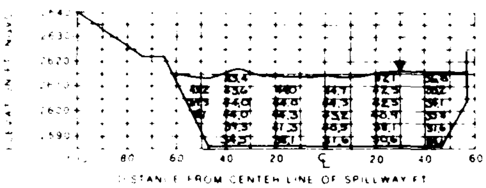
STATION 9+50



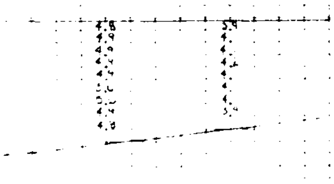
STATION 10+00

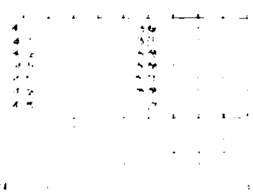


STATION 10+60



STATION 12+00



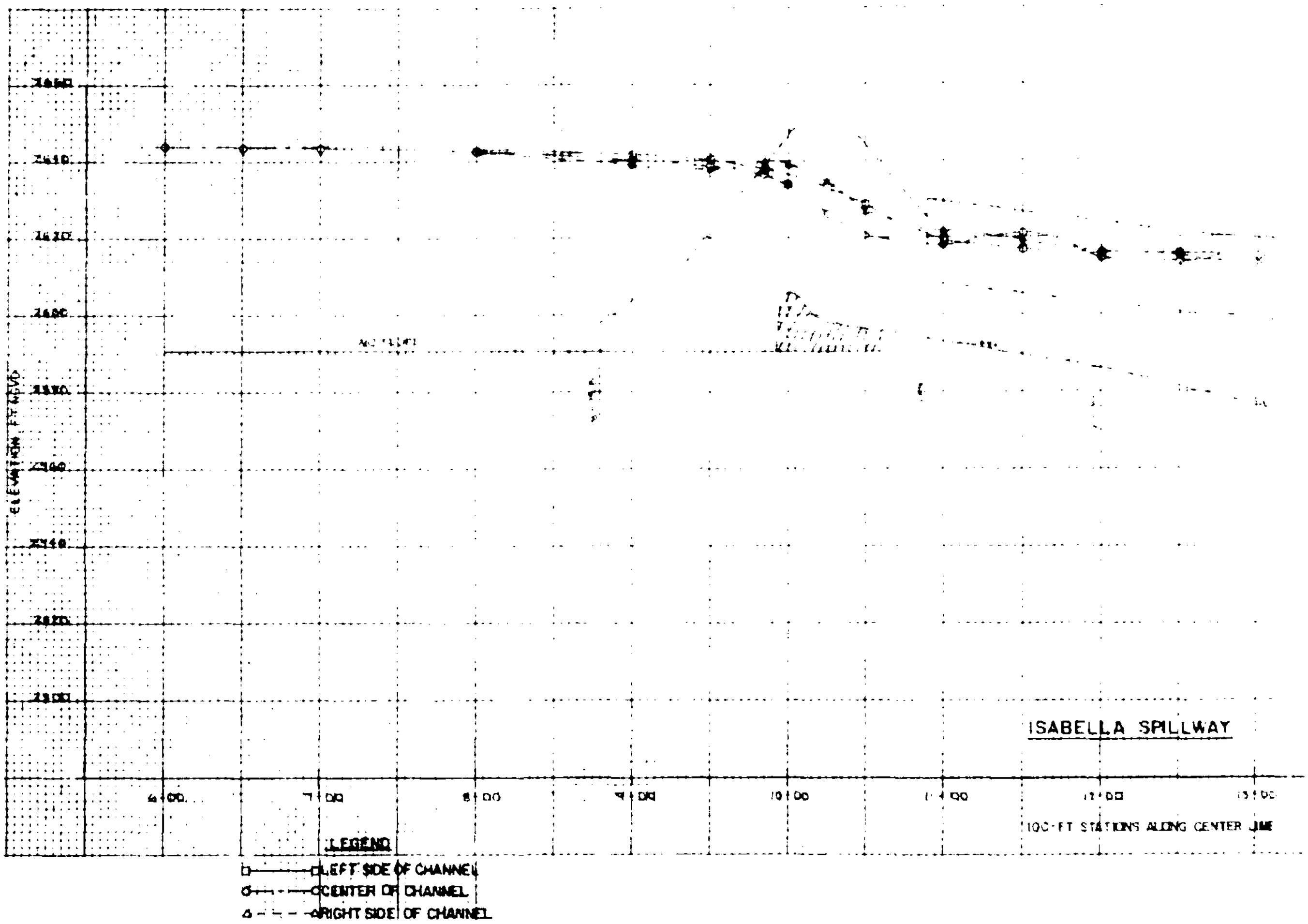


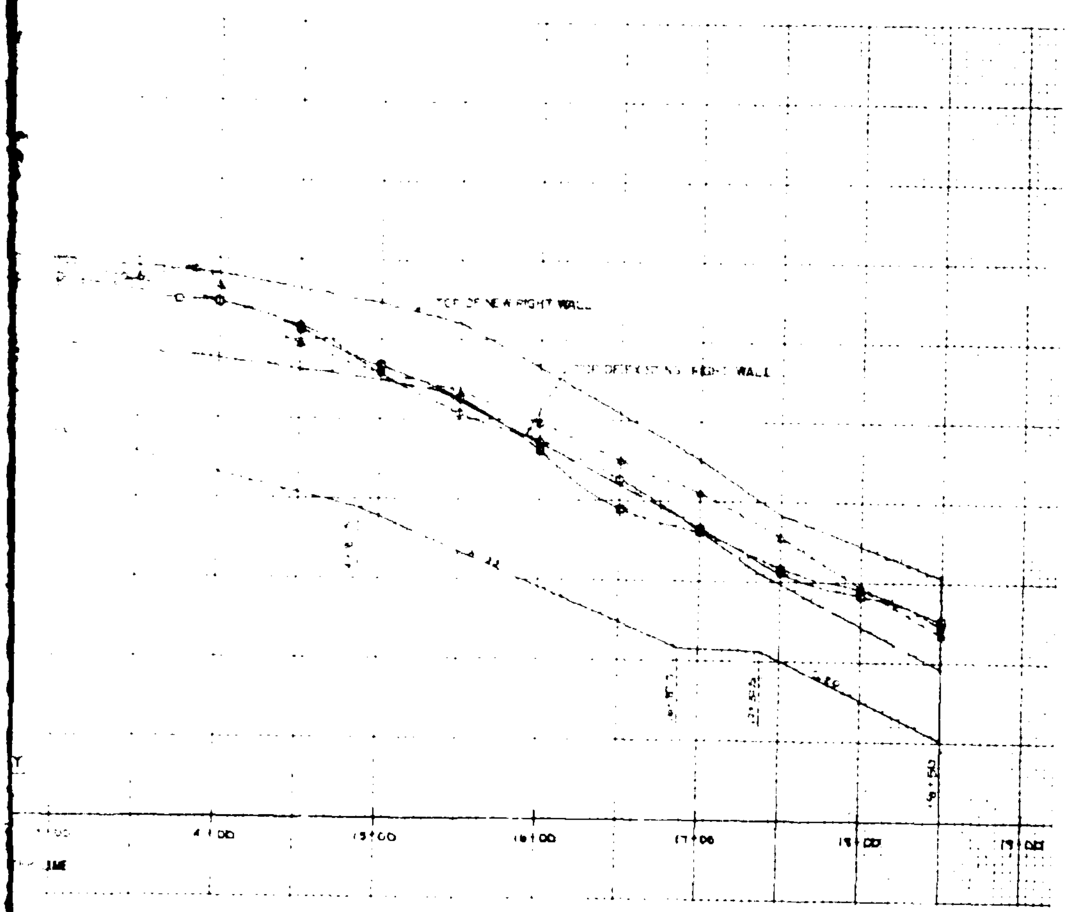
MAXIMUM VELOCITIES

ORIGINAL SPILLWAY DESIGN APPROACH

DISCHARGE 115,500 CFS

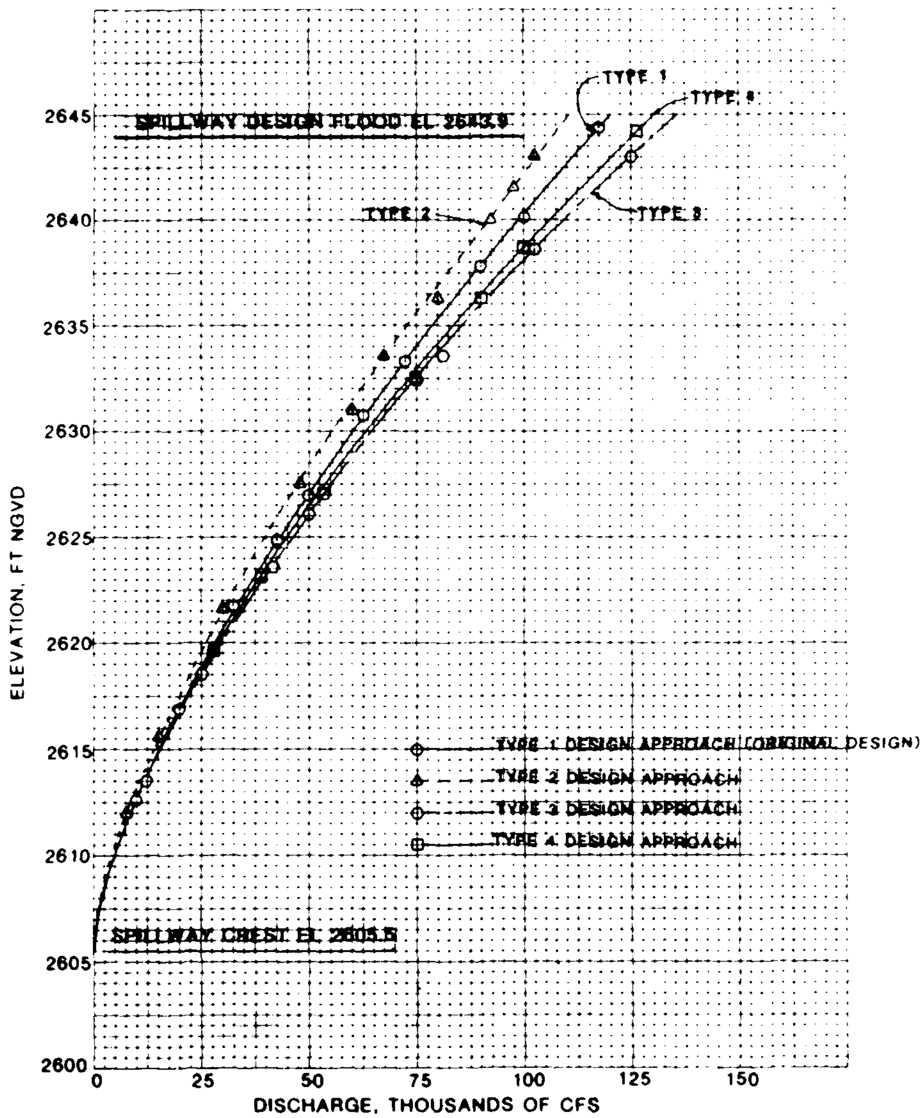
UPPER POOL EL 2643.9


ISABELLA SPILLWAY
ELEVATION, FT NGVD
100-FT STATIONS ALONG CENTER LINE
LEGEND
LEFT SIDE OF CHANNEL
CENTER OF CHANNEL
RIGHT SIDE OF CHANNEL

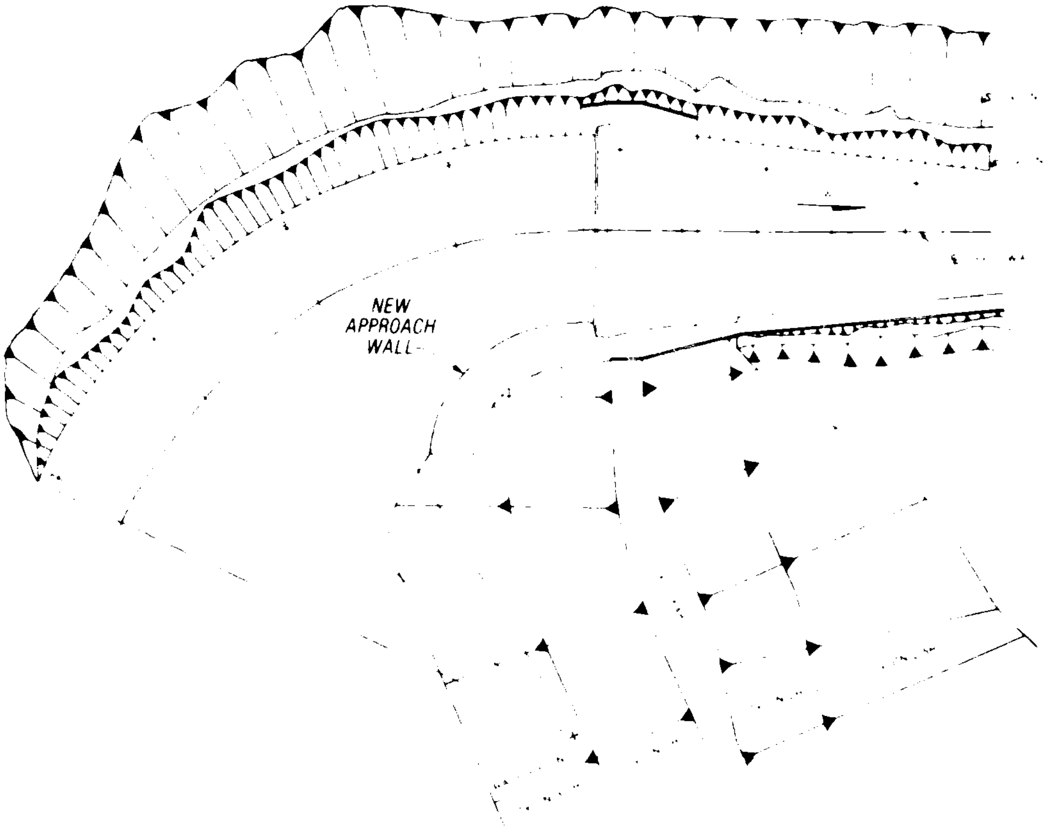


WATER-SURFACE PROFILES
DISCHARGE 115,500 CFS
ORIGINAL DESIGN APPROACH
POOL EL 2643.9

PLATE 4

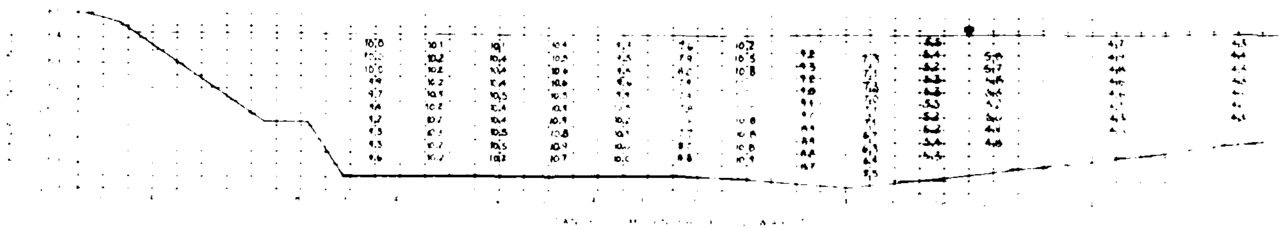


RATING CURVES
OF WEIR CAPACITY
TYPES 1, 2, 3, AND
4 DESIGN APPROACHES

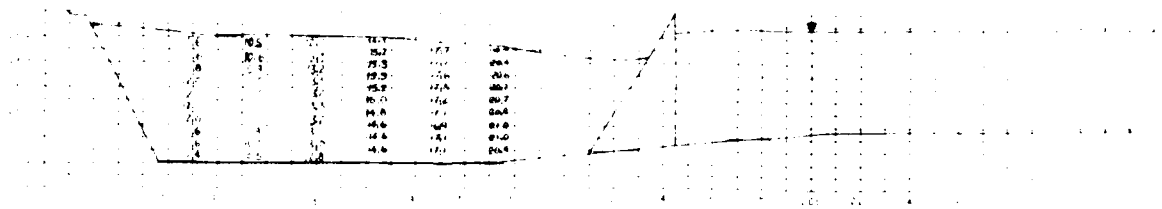


PLAN OF SPILLWAY

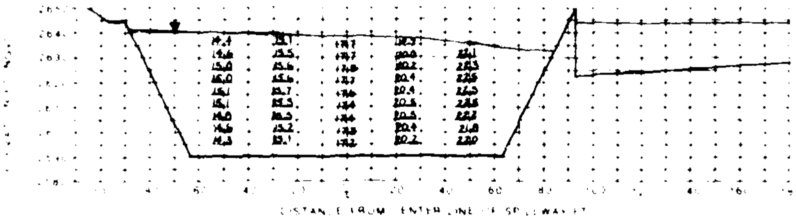
SCALE IN FEET



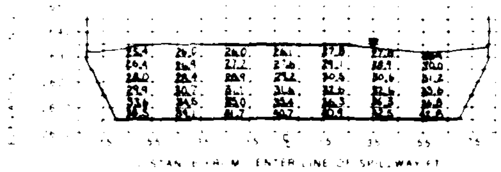
STATION 7+50



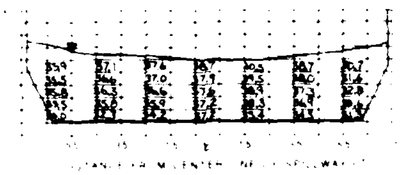
STATION 8+50



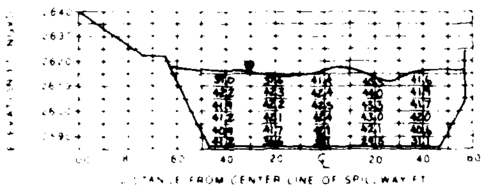
STATION 9+50



STATION 10+00



STATION 10+60



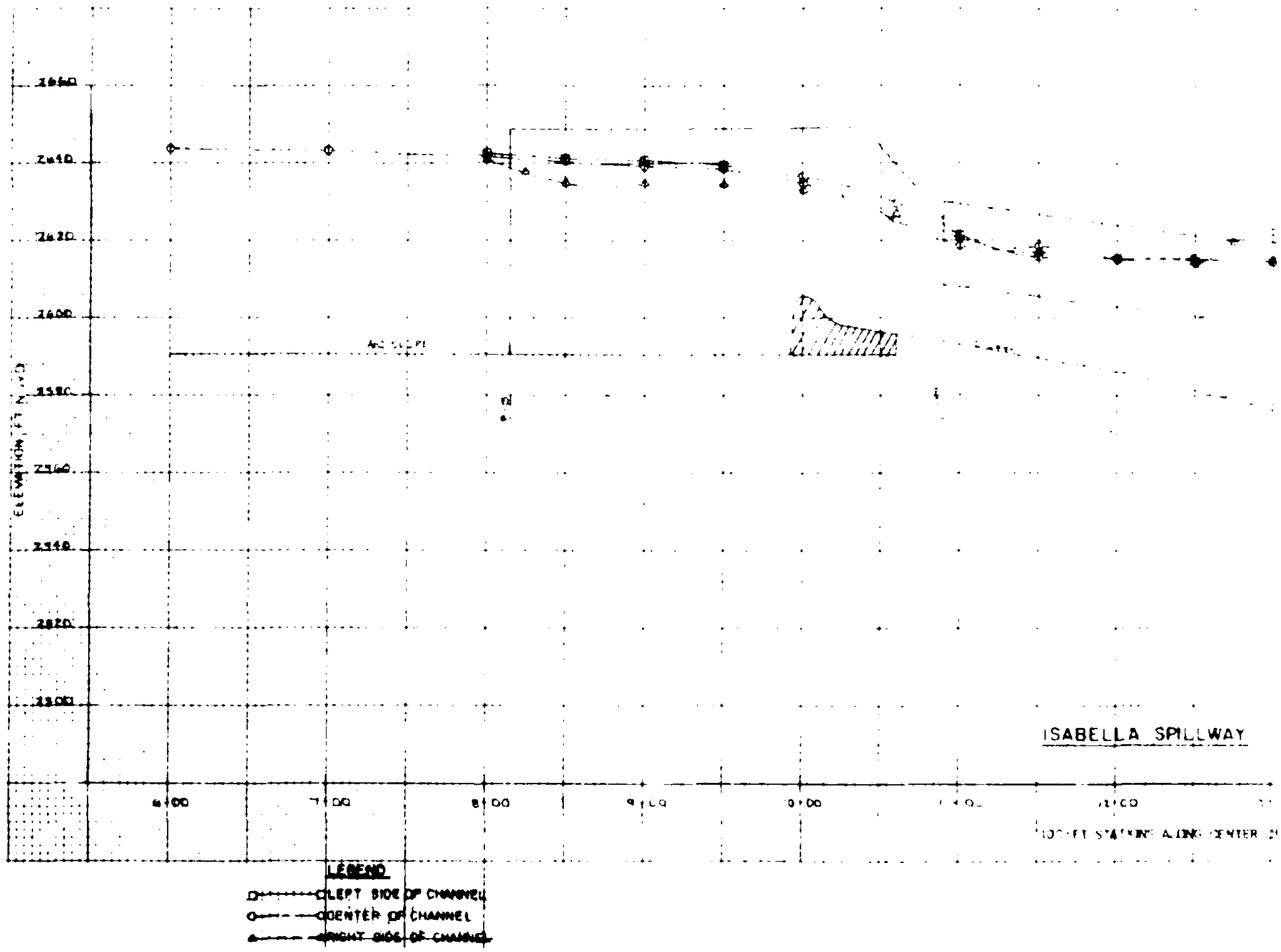
STATION 12+00

MAXIMUM VELOCITIES

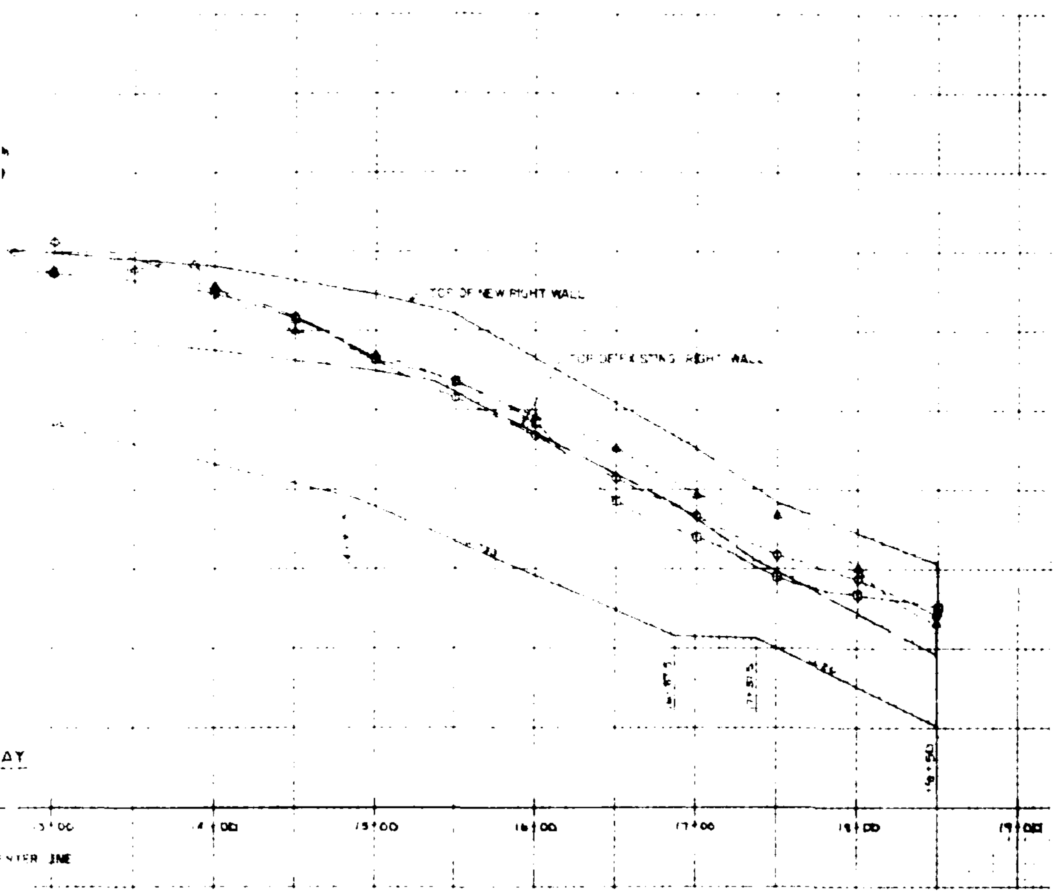
TYPE 3 DESIGN APPROACH

DISCHARGE 130,000 CFS

UPPER POOL EL 2643.9



2660
2640
2620
2600
2580
2560
2540
2520
2500
ELEVATION, FT N.V.D.
6+00
7+00
8+00
9+00
10+00
12+00
ISABELLA SPILLWAY
LEGEND
LEFT SIDE OF CHANNEL
CENTER OF CHANNEL
RIGHT SIDE OF CHANNEL



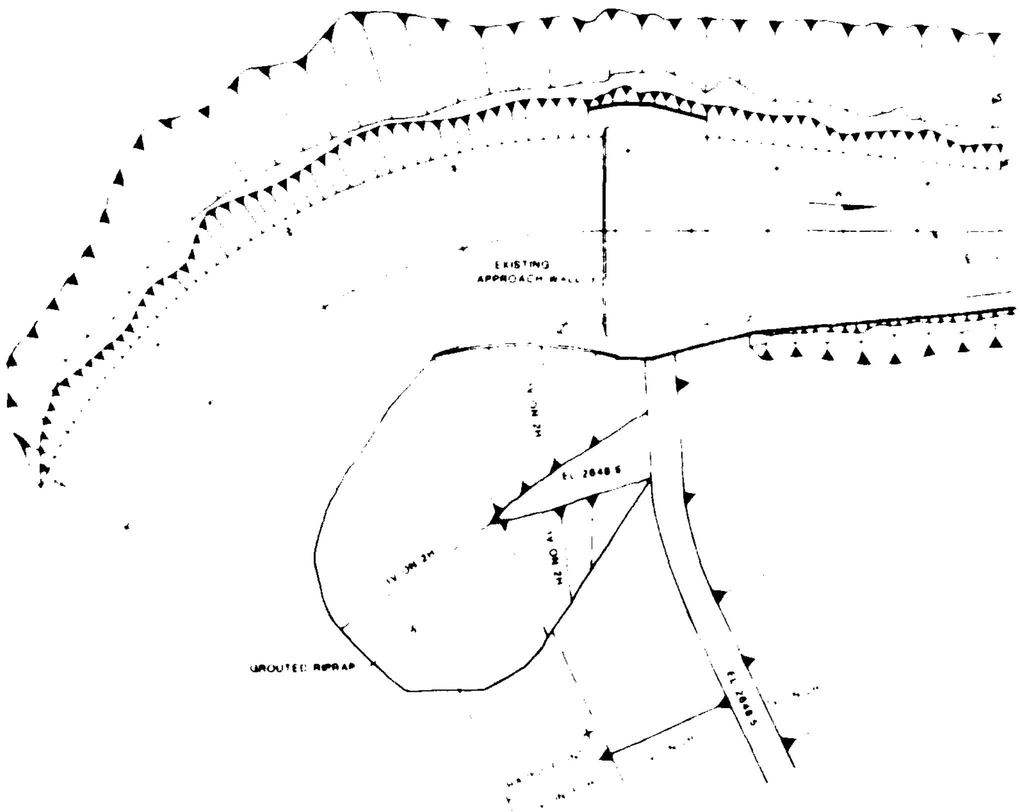
WATER-SURFACE PROFILES

DISCHARGE 130,000 CFS

TYPE 3 DESIGN APPROACH

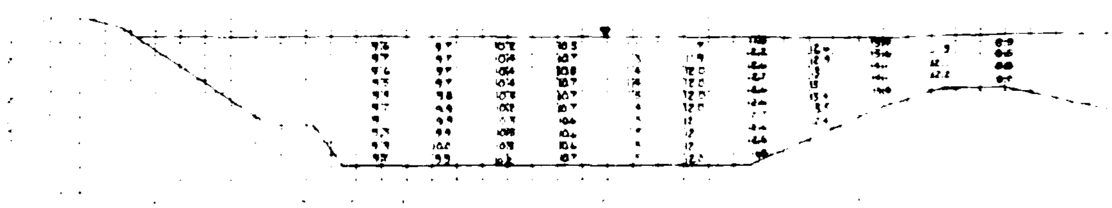
POOL EL 2643.9

PLATE 7

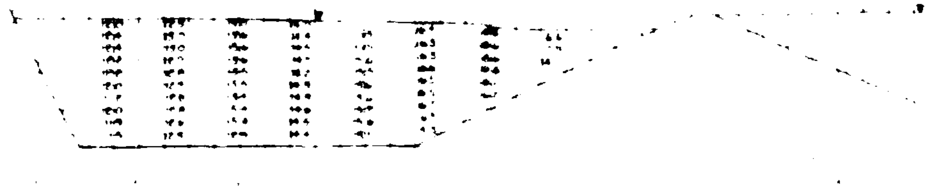


PLAN OF SPILLWAY

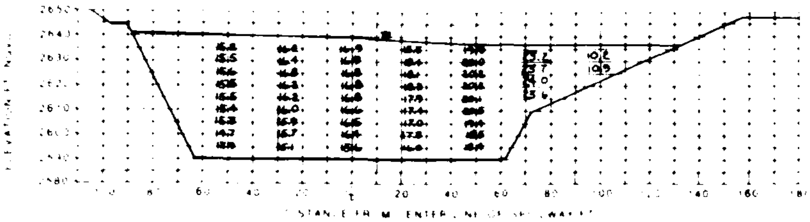
SCALE IN FEET



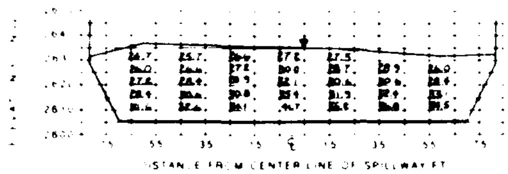
STATION 7+50



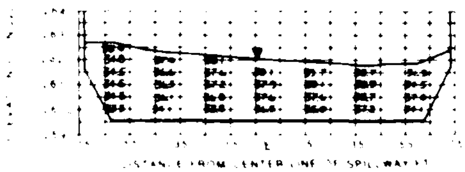
STATION 8+50



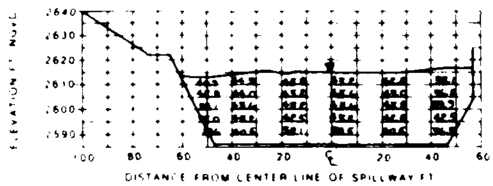
STATION 9+50



STATION 10+00



STATION 10+60



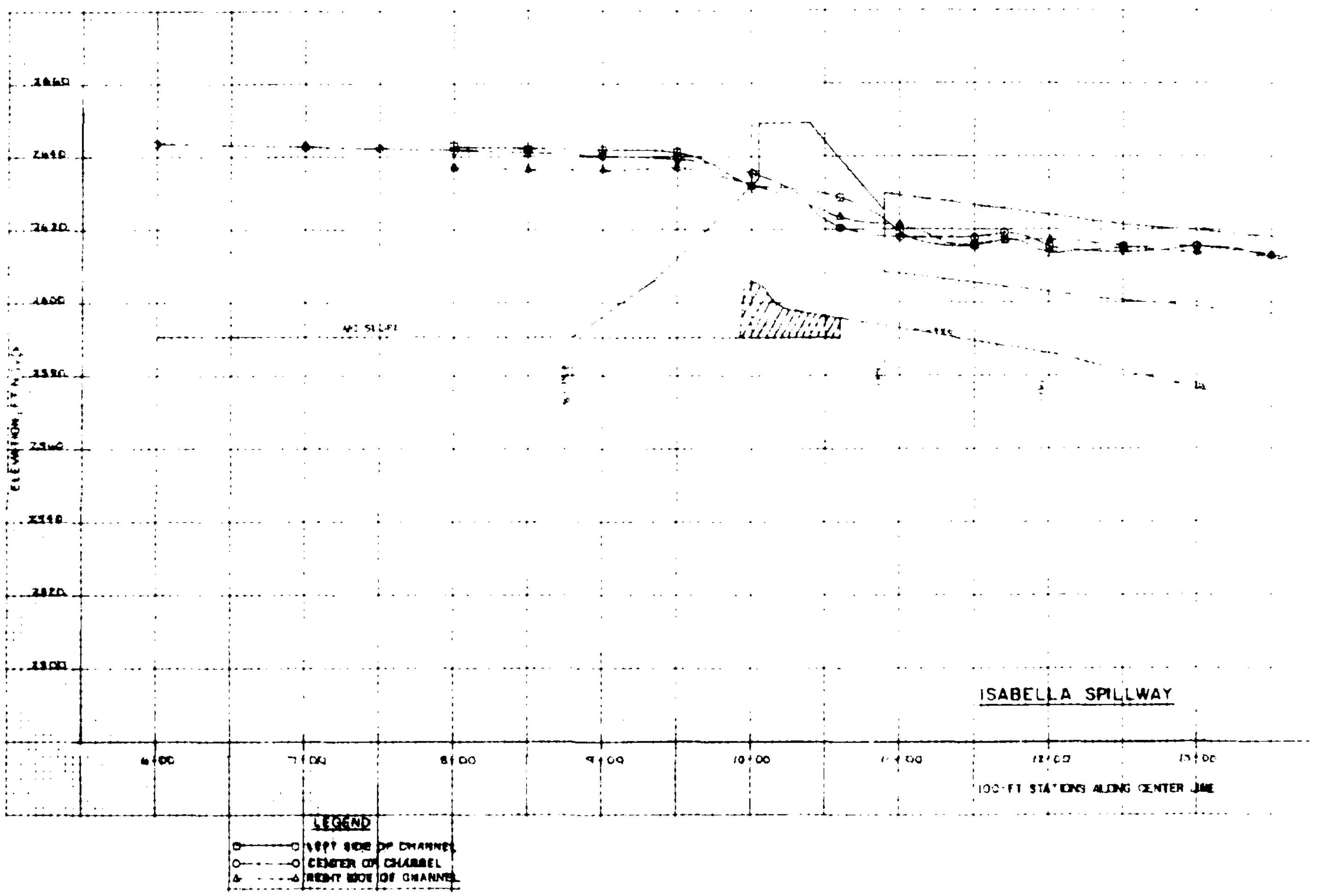
STATION 12+00

MAXIMUM VELOCITIES

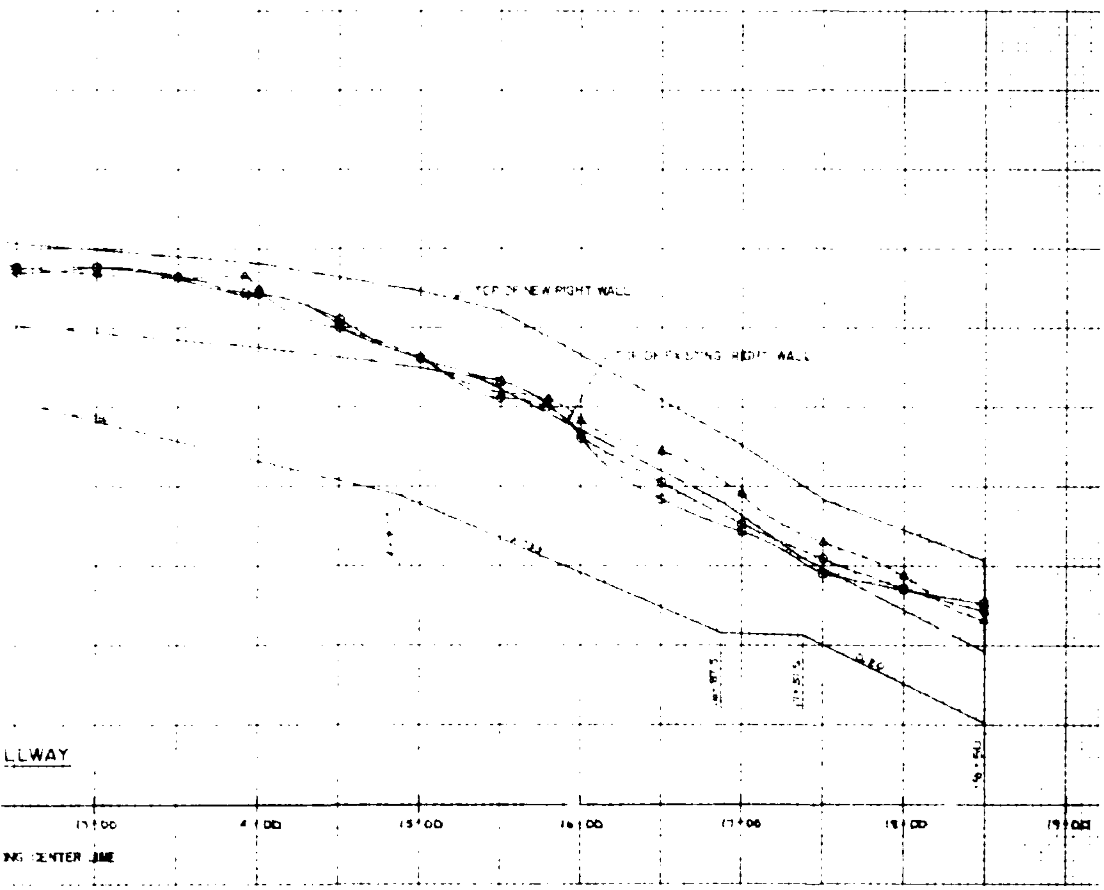
TYPE 4 DESIGN APPROACH

DISCHARGE 125,000 CFS

UPPER POOL EL 2643.9



ISABELLA SPILLWAY
ELEVATION, FT
100-FT STATIONS ALONG CENTER LINE
LEGEND
LEFT SIDE OF CHANNEL
CENTER OF CHANNEL
RIGHT SIDE OF CHANNEL

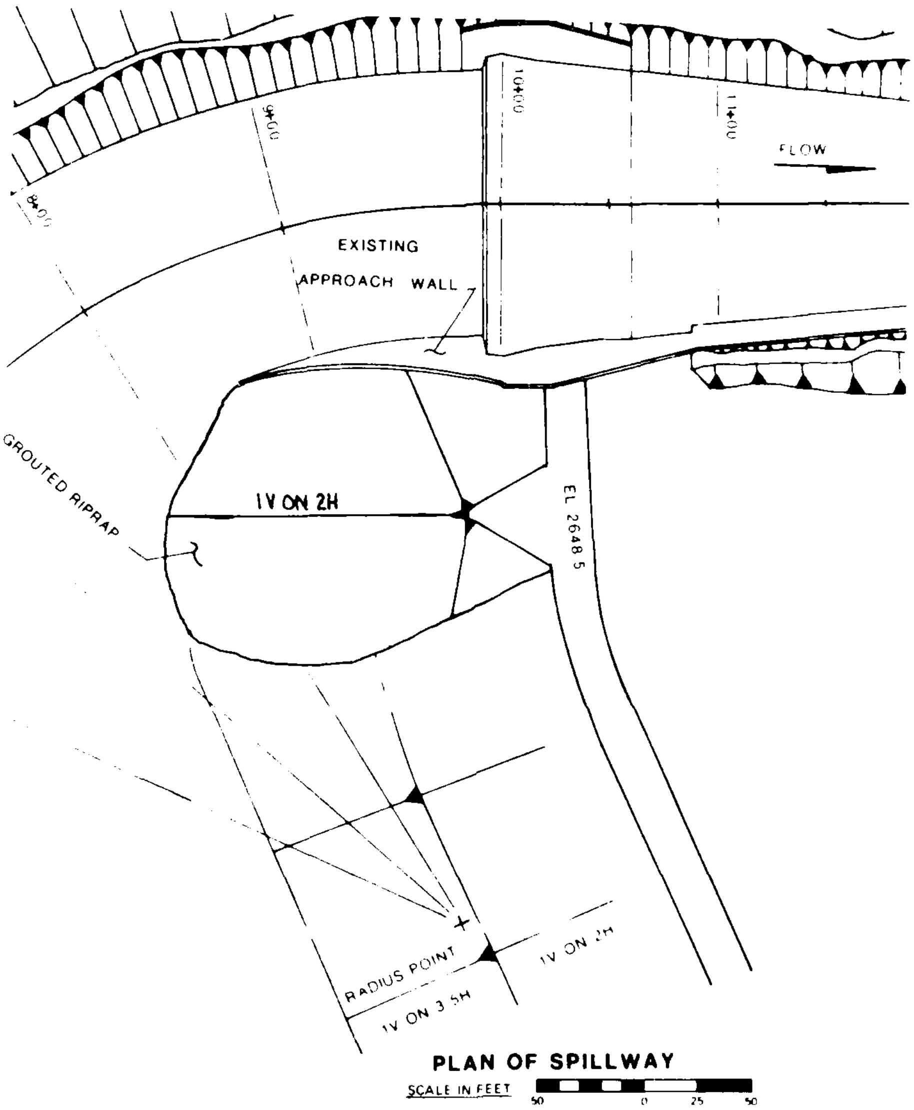


WATER-SURFACE PROFILES

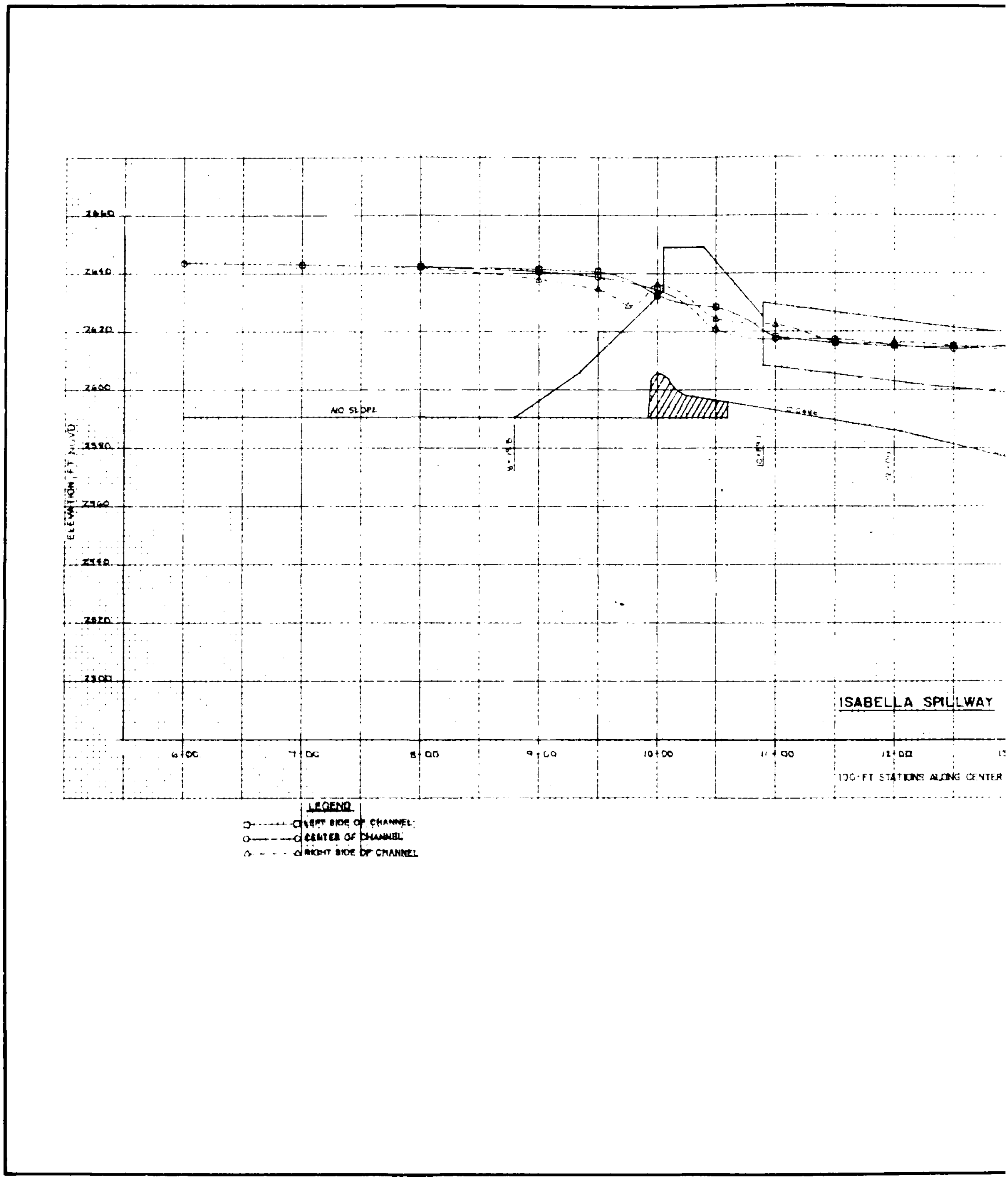
DISCHARGE 125,000 CFS

TYPE 4 DESIGN APPROACH

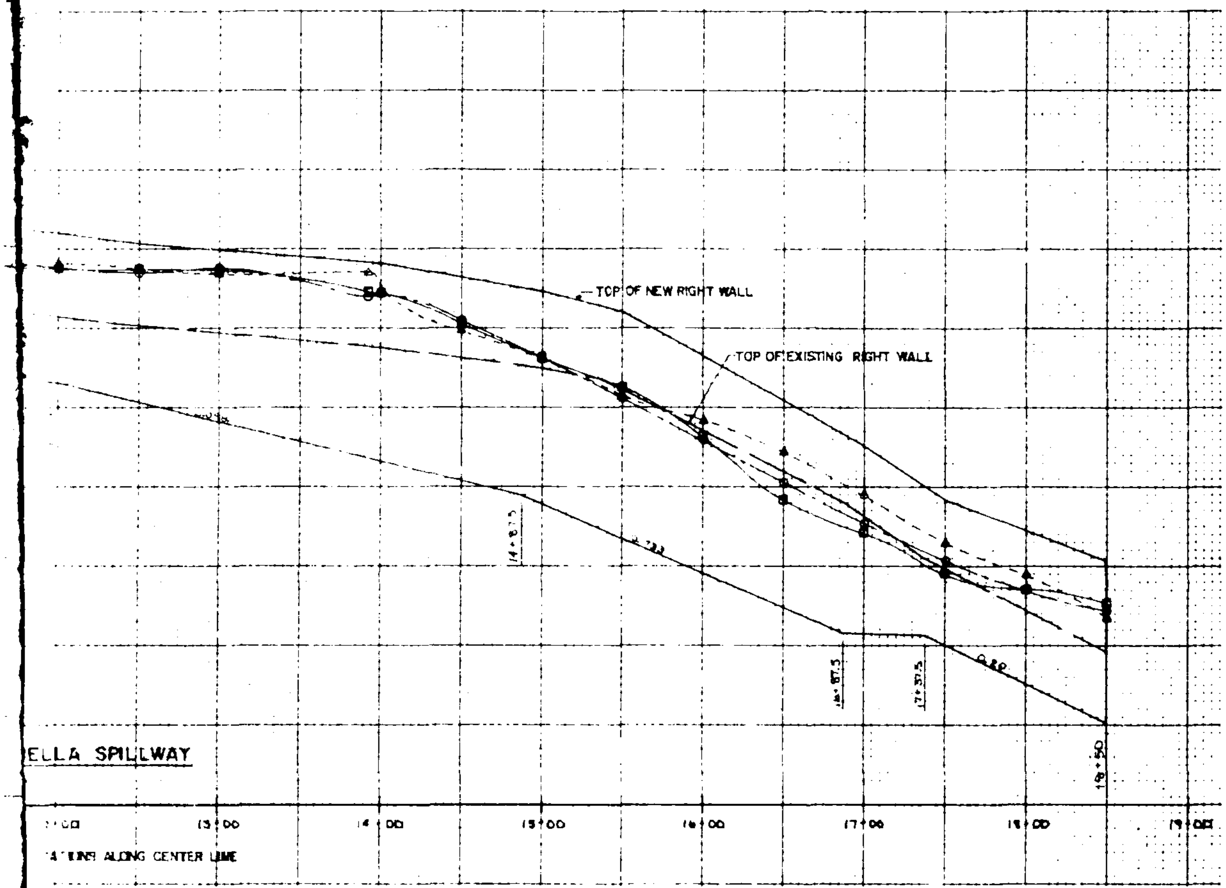
POOL EL 2643.9



TYPE 5 DESIGN APPROACH



2640
2630
2620
2600
2590
2560
2540
2520
2500
ELEVATION, FT NGVD
NO SLOPE
6+00
7+00
8+00
9+00
10+00
11+00
12+00
100-FT STATIONS ALONG CENTER
ISABELLA SPILLWAY
LEGEND
LEFT SIDE OF CHANNEL
CENTER OF CHANNEL
RIGHT SIDE OF CHANNEL

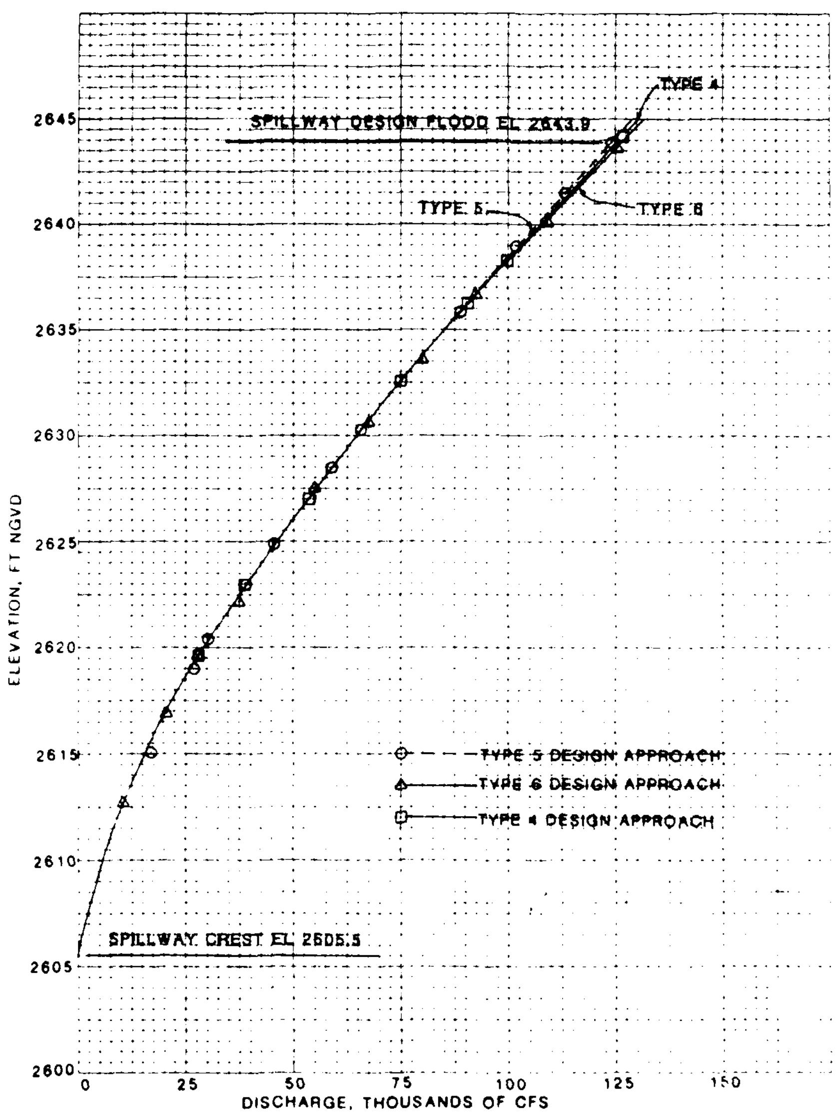


WATER-SURFACE PROFILES

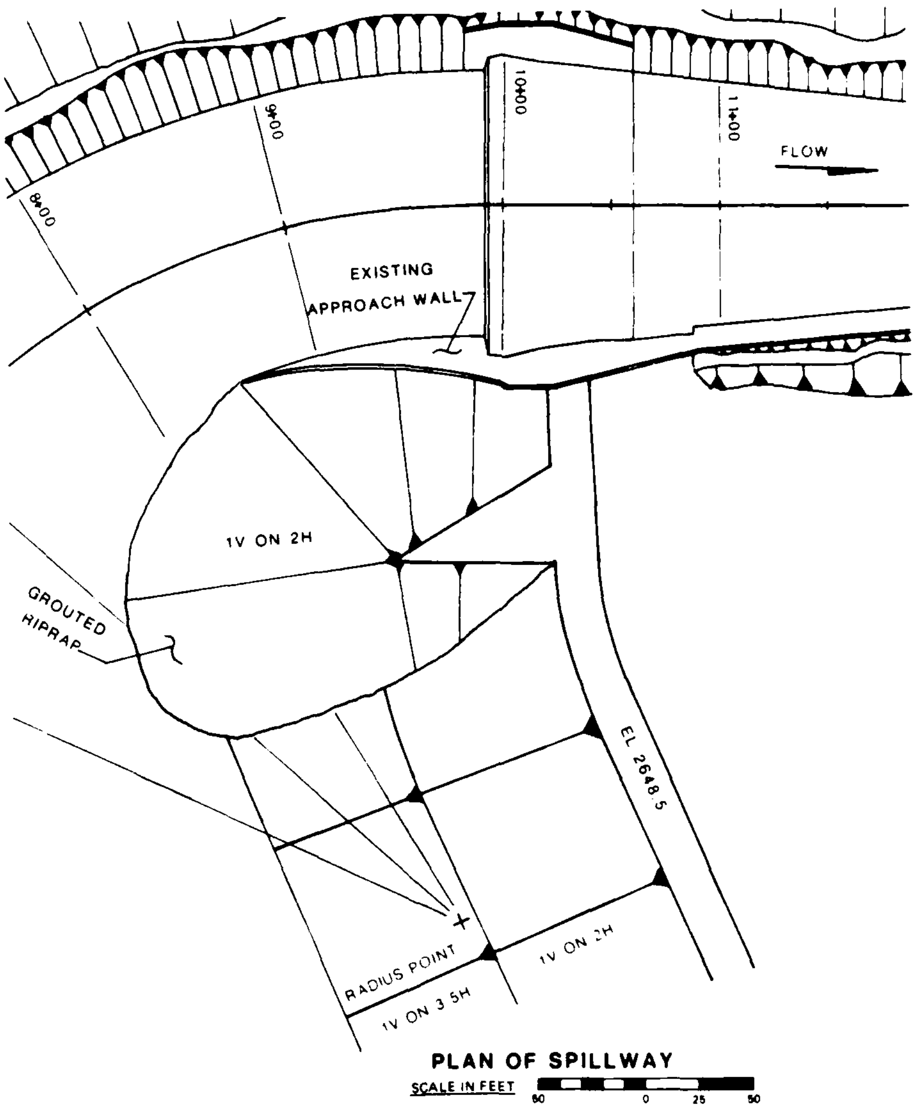
DISCHARGE 124,000 CFS

TYPE 5 DESIGN APPROACH

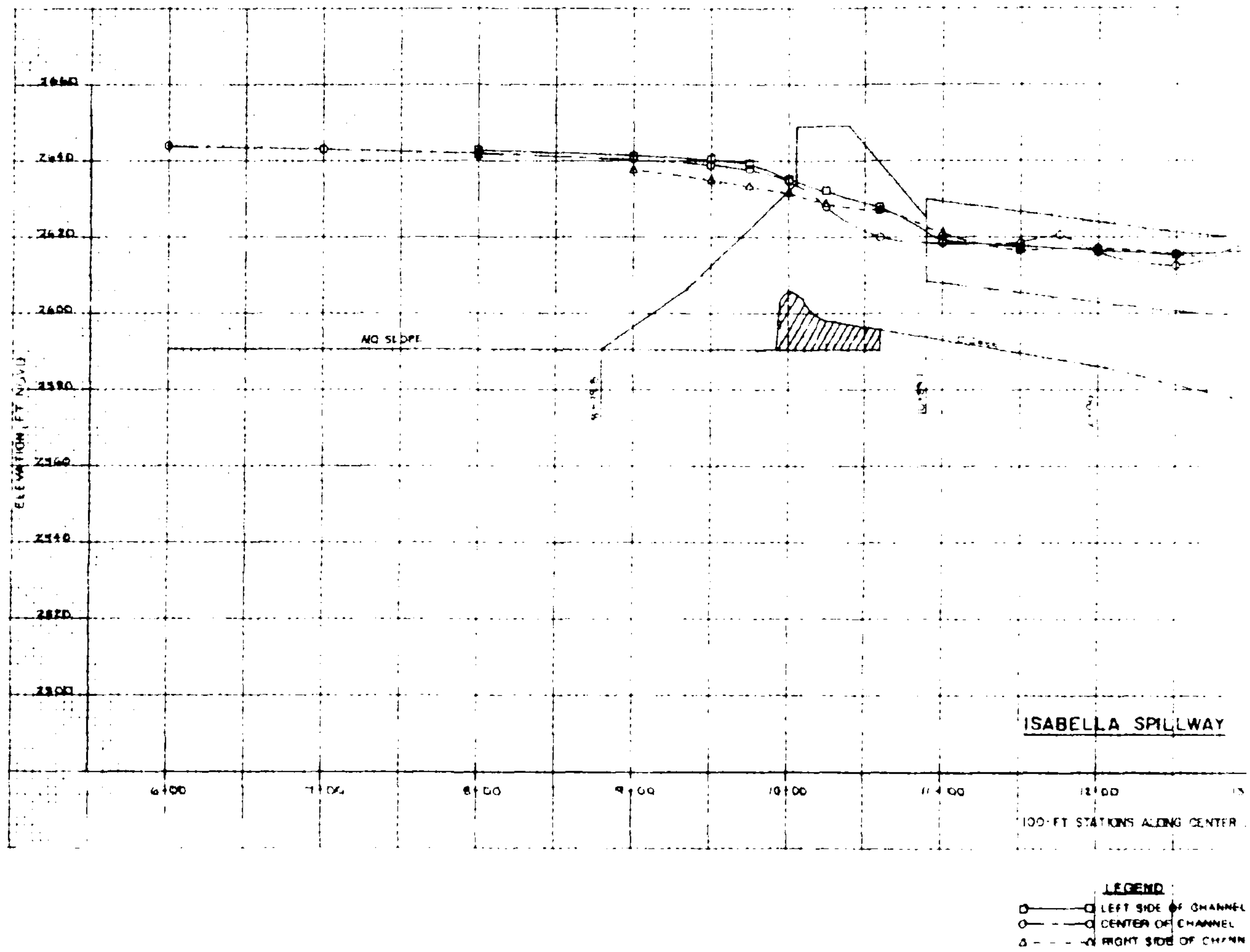
POOL EL 2643.9



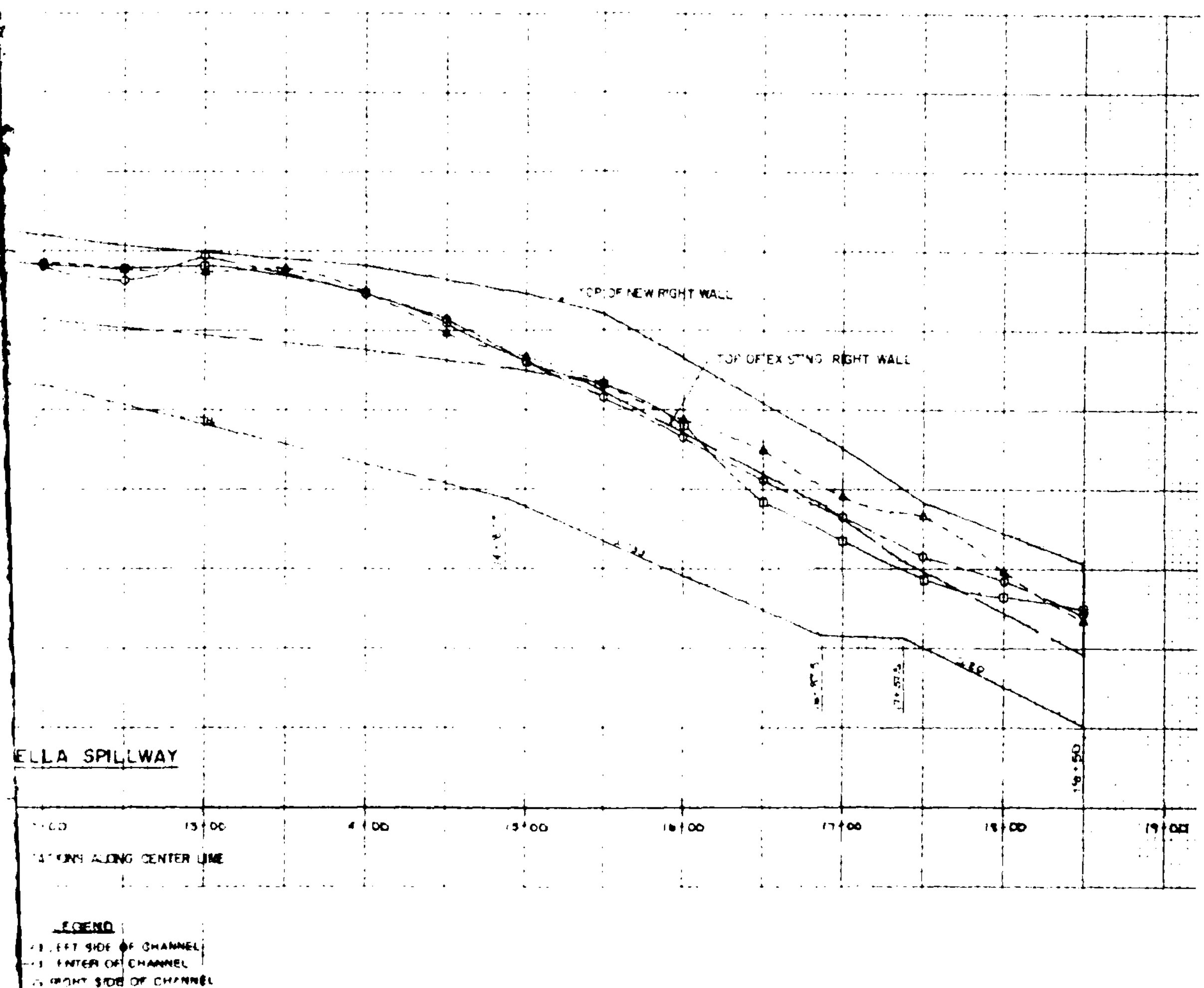
RATING CURVES
OF WEIR CAPACITY
TYPES 4, 5, AND 6
DESIGN APPROACHES



TYPE 6 DESIGN APPROACH



ELEVATION, FT NGVD
2660
2640
2620
2600
2580
2560
2540
2520
2500
NO SLOPE
6+00
7+00
8+00
9+00
10+00
11+00
12+00
100-FT STATIONS ALONG CENTER
ISABELLA SPILLWAY
LEGEND
LEFT SIDE OF CHANNEL
CENTER OF CHANNEL
RIGHT SIDE OF CHANN



WATER-SURFACE PROFILES

DISCHARGE 126,000 CFS

TYPE 6 DESIGN APPROACH

POOL EL 2643.9

ATE
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8